REQ.NO.3-9081

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CONTRACT REPORT NO. OSQ83-00147

TECHNOLOGICAL ASSESSMENT
OF THE
CANADIAN METAL FORMING INDUSTRY

SUMMARY REPORT

205 pp

A report prepared under contract to:
Department of Energy Mines and Resources
Canada Centre for Mineral and Energy Technology
Physical Metallurgy Research Laboratories
Ottawa, Canada

Contract Number: DSS 03SQ.23440-3-9081
Scientific Authority: Dr. A. F. Crawley

February, 1985

JUL 03 1985
MICROMEDIA

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TECHNOLOGY AND THE METALFORMING INDUSTRY

The metalforming industries comprise a significant proportion of the manufacturing base of any industrial country. These industries are the foundation for the production of products such as automobiles, major appliances, aircraft, machinery, and countless other goods. A successful and technologically competitive metalforming industry is essential to the economic well being of every industrial country.

This report discusses the results of a major study of world-wide metalforming technology. The study was commissioned by the Physical Metallurgy Research Laboratory of the Canada Centre for Mineral and Energy Technology (CANMET) as part of its Technology Transfer program. The study provides a comparative assessment of the level of technology employed in the metalforming industries of Canada, the United States, Japan, Sweden, West Germany, France, and the United Kingdom. The study was commissioned in November, 1983, and completed in December, 1984.

1.1 Introduction

The level of technology employed in an industry sector has a pervasive effect on the competitiveness of that sector. This is true not only of the "high tech" industries of computers and telecommunications, but also of industries which have been regarded as "low tech" such as the metalforming industries.

The metalforming industries, defined here as the sheet metalforming (stamping, pressing, rollforming and spinning) and forging industries, are undergoing a period of rapid technological change. This change is occurring on a worldwide basis and at all stages of the manufacturing cycle, from metal production to final assembly. Increasingly, the metalforming industry is being transformed into a high technology industry. This transformation is necessitating greatly expanded knowledge of the behaviour of materials under deformation conditions, new manufacturing methods, quality control, and computers. These changes are not occurring at the same rate in all countries, nor in all branches of the metalforming industry. The Japanese automobile industry is perhaps the best example of a country and an industry which has successfully exploited technology in advance of its competitors.

The response of Canadian manufacturers to this new competitive environment has been of concern to a wide variety of parties ranging from government departments and agencies to labour unions. Concern has been expressed that Canada may not be competitive due to a failure to invest in new technology and to develop new management techniques. This report is designed to explore the impact of technology on the competitiveness of the Canadian metalforming industry. It provides a comparative analysis of the level of technology employed in the metalforming industries of Canada, the United States, Japan, and Europe.

For the purposes of this report, technology has been defined to include:

- raw materials technology
- processing and manufacturing technology
- design technology
- research and development.

Included in this definition is consideration of such factors as:

- raw material availability and quality
- computer-aided design and manufacture systems
- robotics and other forms of advanced manufacture and materials handling
- automated non-destructive testing and inspection systems
- productivity, waste reduction, and product quality
- research and development capability
- alternative materials and associated processes.

A primary focus of the study was on the identification of technology gaps which exist between Canadian industry and foreign industry. This included the identification of new or potential technology applicable to the industry; the capability of Canadian industry to assimilate new technologies; and the identification of methods of transferring new technologies to industry from research and development sources.

The range of technologies examined included:

- supplier technology related to the provision of stock materials, including consideration of metallurgical, dimensional, and surface specifications;

- stock preparation factors such as shearing and heating practices;

- materials handling technology, including use of robotics;

- die design, including use of CADD systems;

- die manufacture, including CAM systems;
- press design;
- microelectronics technology as applied to metalforming processes;
- assembly and finishing operations, including heat treatment;
- non-destructive testing and inspection processes;
- management practices as they influence production technology;
- competing materials and processes such as plastics, casting, and powder metallurgy.

1.2 Methodology

This report is based on research conducted in late 1983, and during 1984. The research methodology consisted of:

- extensive analysis of published data relating to production of both finished products and components;
- extensive review and analysis of published information related to new materials, processes, production methods, and equipment;
- collection and analysis of trade catalogues, bulletins, and technical literature of raw material suppliers, fabricators, and machinery and equipment suppliers;
- an extensive series of interviews and plant tours with sheet metal processors, forging companies, equipment suppliers and raw material suppliers in Canada, the United States, Europe, and Japan. A complete list of respondents is to be found in Appendix A.

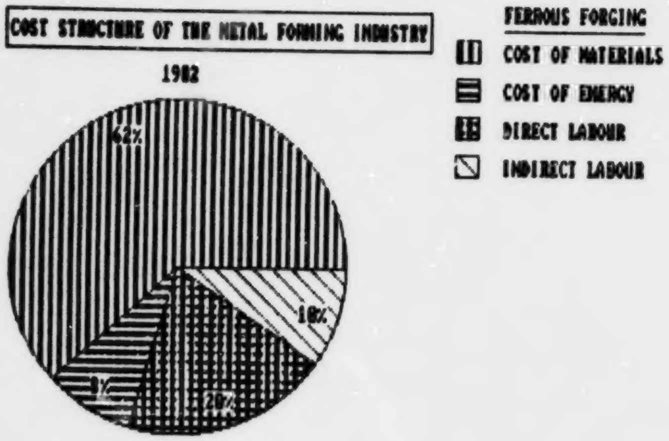
1.3 Report Structure

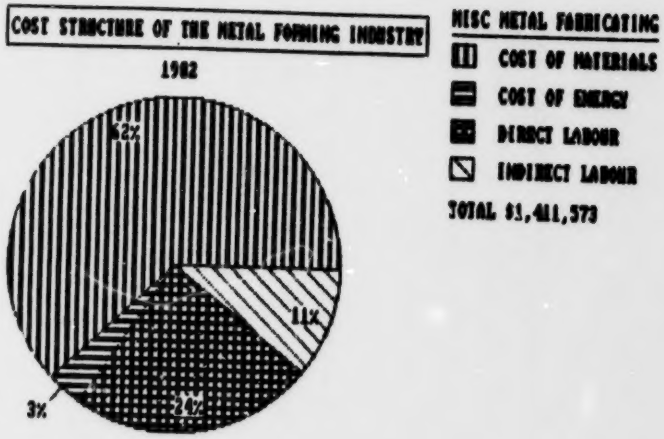
This report is three volumes. The Summary Report provides an overview of the main reports. The report details the principal findings, conclusions, and recommendations of the study under the general topics of the sheet metalforming industry and the forging industry.

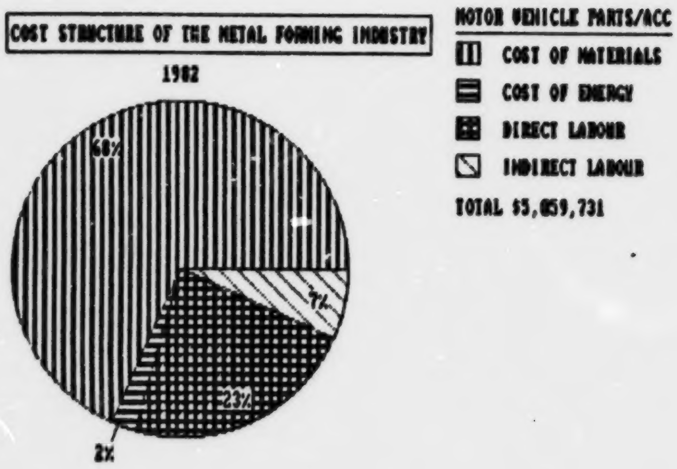
Volume I of the main report discusses the stamping and pressing industry. Volume II discusses the forging industry. Within each volume the analysis proceeds from an initial discussion of market structure. This is followed by a series of chapters discussing and analyzing the industry from raw materials through to inspection of the finished product. The final sections of each volume detail new technological developments and the research requirements of Canadian industry, including the role of CANMET in meeting those research requirements.

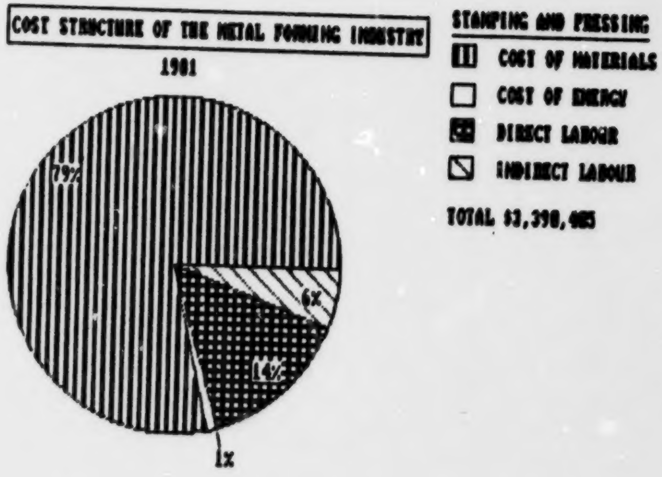
An extensive series of appendices is included with Volumes I and II of the main report. These appendices provide additional information related to the discussion of issues raised in the main reports.

EXHIBIT 1









Source: Statistics Canada

I - EXECUTIVE SUMMARY

This report provides a technological assessment and comparison of technology employed in the sheet metalforming and forging industries in North America, Japan, and western Europe. The report is based on both primary and secondary data, including an extensive series of plant visits in each region of interest.

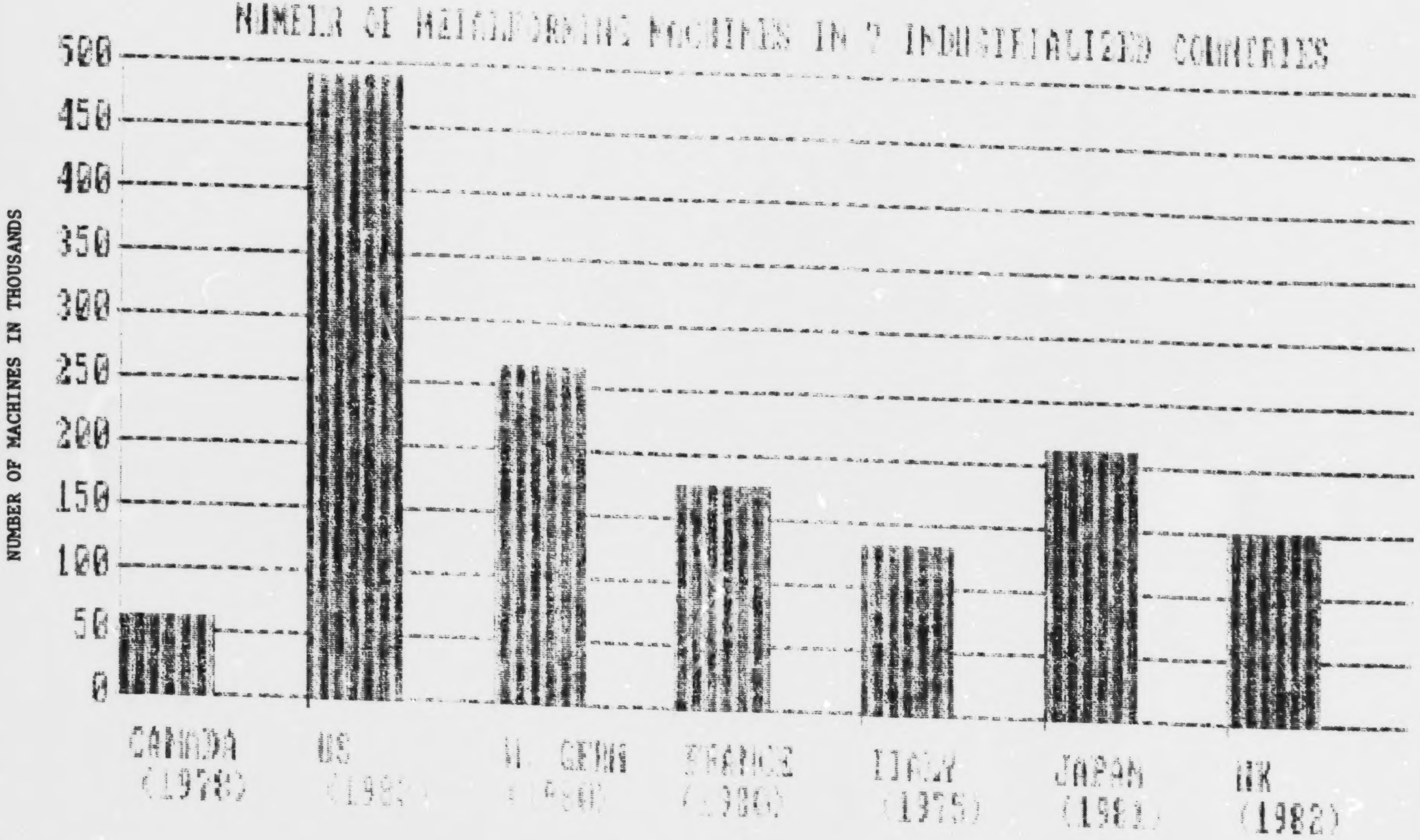
In discussing the technology of the metalforming industry, and the role of technology in the competitiveness of the industry, it is key to understand two elements of the cost structure of the industry. These are:

a) the importance of raw material costs
b) the importance of the ratio

$$\frac{\text{usable output}}{\text{theoretical capacity}}$$

Raw material costs are the most significant element of manufacturing cost in the metalforming industries. They represent at least 50% of the sales value of any sheet metal or forged product. In some cases, materials cost can account for over 80% of the sales price of a product. Labour and energy costs represent a much less substantial proportion of total costs. Typically, direct labour represents less than 20% of the total price of a product. Energy costs typically represent less than 10% of costs. These factors are illustrated in Exhibit 1 for several components of the Canadian metalforming industry. There are only slight differences between the distribution of costs in other regions such as the United States, Japan, and Europe compared to Canada. Thus, a key ingredient of success in the metalforming industry is increasing or maximizing the yield from a given amount of raw material. This may be achieved by a number of means, chief of which are:

EXHIBIT 2


NUMBER OF METALFORMING MACHINES IN 7 INDUSTRIALIZED COUNTRIES
NUMBER OF MACHINES IN THOUSANDS
500
450
400
350
300
250
200
150
100
50
0
CANADA (1978)
US (1983)
W. GERM (1980)
FRANCE (1980)
ITALY (1975)
JAPAN (1981)
UK (1982)

- die design
- process design
- process technology

The other key factor to consider is the process yield. This refers to the ratio:

$$\frac{\text{usable product}}{\text{theoretical capacity}}$$

and is determined by the formula:

$$\begin{array}{c}\text{rated}\\ \text{capacity}\\ \text{(parts/hr)}\end{array} \times \begin{array}{c}\text{available}\\ \text{hours}\end{array} \times \begin{array}{c}\text{machine}\\ \text{utilization}\\ \text{(hrs/year)}\end{array} \times \left(\begin{array}{c}\text{1-defect}\\ \text{rate}\\ \end{array}\right) = \begin{array}{c}\text{output of}\\ \text{usable}\\ \text{product}\end{array}$$

Thus technology and procedures which increase machine utilization and reduce the rate of defects can have a significant impact on the ultimate cost of manufacture of a product.

Throughout this report, reference will be made to these two key elements of success in the metalforming industry. The interaction of various elements of product, process and management technology with these factors is a major thesis of the report.

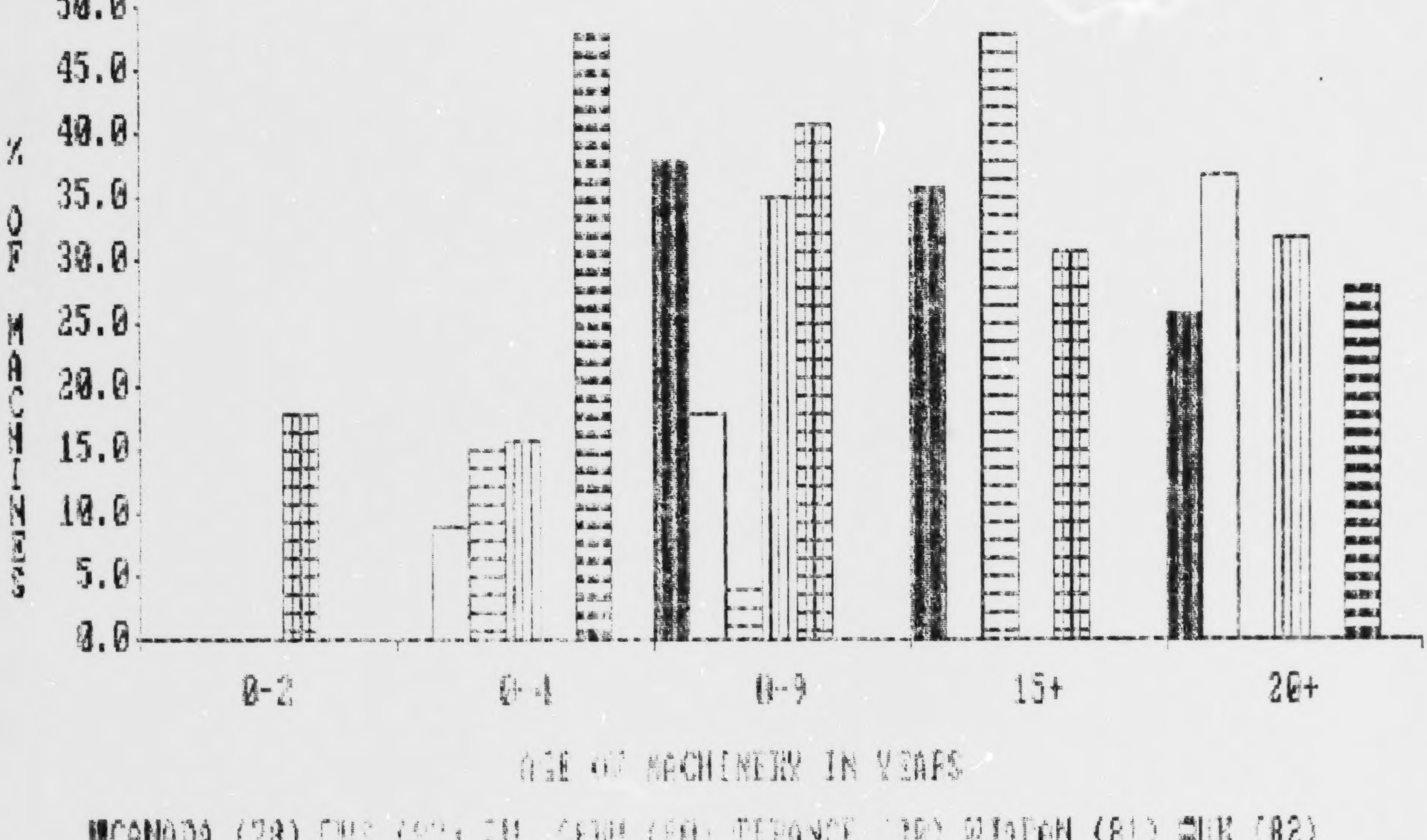
Conclusions

The principal conclusion of the research and analysis are:

- Canadian industry employs technology quite similar to that used by the U.S., and European companies, as well as Japanese companies.
- Differences in technology between Canadian industry and industry in other countries relate more to scale than to lack of awareness of technology. This best illustrated by reference to Exhibits 2 and 3 which show the distribution of metalforming machines in major industrialized countries by number and age.

EXHIBIT 3

AGE OF METALWORKING MACHINERY IN 6 INDUSTRIAL NATIONS



- The level of knowledge of metalforming behaviour is generally lower in North America than in Japan or western Europe.

- The use of advanced manufacturing technologies such as CADD/CAM, robotics, and automated non-destructive testing and inspection equipment is limited both in Canada and elsewhere. Only the largest companies have adopted these technologies in a major way, with the automotive and aerospace industries being the most advanced.

- The North American automotive industry is adopting a "high technology fix" as the solution to its productivity and quality problems, and is forcing the supplier industry to follow suit. Relatively few Canadian companies are equipped from either a technical or management situation to adapt themselves to this rapidly changing environment.

- Significant productivity advances are available to Canadian industry through use of simple, well-proven techniques such as:
    - quick die change procedures
    - use of simple transfer devices
    - use of statistical process control procedures
    - use of transfer press technology.

- The Japanese have exploited these techniques to a high degree, and owe much of their competitive success to these techniques rather than the extensive use of highly automated design, production, and assembly technologies.

- The quality of domestically produced raw material for the Canadian metalforming industry is generally regarded as good, and superior to that available from U.S. sources of supply.

- European suppliers appear to provide material equivalent in quality to that available from U.S. mills.

- Japanese ferrous and non-ferrous metals producers tend to offer superior quality material.

- The average level of rejection of raw material was reported to be as follows:

Rejected Steel as a Per Cent of Purchases
(tonnage basis)

	Sheet	Forging Stock
Canada	1%	2%
United States	2.5%	2.5%
Europe	1.5%	2.5%
Japan	0.5%	0.5%

- The superior quality of Japanese raw materials assists Japanese metalforming companies in producing products more efficiently and with greater quality.

- In-process reject rates are significantly lower in Japan than in the other countries examined. This superior quality is not the result of the application of new technology. Rather, it is the result of a concerted effort by management and labour (especially management) to develop efficient manufacturing methods and to apply statistical process control (SPC) procedures at all stages of manufacture, from raw materials to finished products.

  Average reject rates in the metalforming industry are:

	Sheet Metal	Forging
Canada	2% - 3%	2% - 3%
United States	2% - 3%	2% - 3%
Japan	0.5%	0.5%
Europe	2% - 5%	2% - 4%

- The Canadian metalforming industry does not have available to it from domestic sources as broad a range of sheet metal and forging stock as the industry in other jurisdictions. This deficiency in terms of domestic supply is primarily related to market size, rather than to technical factors.

- The Canadian metalforming industry undertakes very little research and development work. The industry relies primarily on the results of work in other countries for its knowledge of metalforming behaviour, equipment, and production processes. The industry makes little use of outside research agencies, universities and other sources of information.

- The Canadian metalforming industry has expressed a need for more detailed information on the forming characteristics of a wide variety of materials. The most urgent requirements are for detailed data on:

  - high strength, low alloy (HSLA) and high strength steels (HSS);
  - continuously annealed (CA) steels;
  - precoated (galvanized, galvalume, prepainted, aluminized) steels
  - continuously cast steels for forging;
  - microalloyed steels for forging;
  - steels for cold and warm forging;
  - composite materials;
  - non-ferrous sheet and bar stock materials;
  - powder metallurgy materials and processes.

- The Canadian metalforming industry has a requirement for CADD programs incorporating finite element analysis (FEA) which would be suitable for examining the forming behaviour of sheet materials and bar stock, and for evaluating die design alternatives using 16 and 32 bit computers.

  Existing programs are too general to be of specific use to the metalforming industry.

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ÉVALUATION DE LA TECHNOLOGIE DE L'INDUSTRIE CANADIENNE DE PROFILAGE DU MÉTAL

RAPPORT SOMMAIRE

Un rapport commandée par
Ministére De L'Energie, Des Mines Et Des Ressources
Centre Canadien De La Technologie Des Minéraux
Et De L'Energie
Laboratoires De La Métallurgie Physique
Ottawa, Canada

Numero De Contract: DSS 03SQ.23440-3-9081
Autorité Scientifique: Dr. A. F. Crawley

Février, 1985

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L'INDUSTRIE DE PROFILAGE DU MÉTAL FACE À LA TECHNOLOGIE

Les industries de profilage du métal forment une partie importante du secteur manufacturier des pays industrialisés. C'est en effet sur elles que repose la production d'automobiles, de gros appareils, d'avions, de machines et d'une vaste gamme d'autres produits. Une industrie de profilage du métal prospère et concurrentielle sur le plan technologique est essentielle au bien-être économique de tout pays industrialisé.

Le présent rapport analyse les conclusions d'une vaste étude portant sur l'industrie internationale de profilage du métal. Cette étude a été commandée par les Laboratoires de la métallurgie physique du Centre canadien de la technologie des minéraux et de l'énergie (CANMET) dans le cadre de son programme de transfert des technologies. L'étude présente une évaluation comparative du niveau de technologie utilisé dans les industries de profilage du métal des pays suivants : le Canada, les États-Unis, le Japon, la Suède, l'Allemagne de l'Ouest, la France et le Royaume-Uni. Commandée en novembre 1983, l'étude s'est terminée en décembre 1984.

1.1 Introduction

Le niveau de technologie dans un secteur industriel se répercute sur la compétitivité de ce secteur. Cela s'applique non seulement aux industries de haute technologie des ordinateurs et des télécommunications, mais aussi aux industries appelées de ''basse technologie'' comme les industries de profilage du métal.

Les industries de profilage du métal comprenant, aux fins du présent rapport, les industries de profilage de la tôle (estampage, emboutissage, laminage et repoussage) et de forgeage ont amorcé le virage technologique. Cette évolution se fait sentir à l'échelle internationale et touche toutes les étapes du cycle de fabrication, de la production du métal à l'assemblage final. De plus en plus, le profilage du métal est en passe de devenir une industrie de haute technologie. Cette transformation exige une connaissance beaucoup plus approfondie du comportement des matériaux dans des conditions de déformation, de même que des nouvelles méthodes de fabrication, du contrôle de la qualité et des ordinateurs. Ces changements ne surviennent pas au même rythme dans tous les pays ni dans tous les secteurs de l'Industrie de profilage du métal. L'industrie japonaise de l'automobile est peut-être le meilleur exemple pour illustrer comment ce pays et cette industrie ont su tirer profit de la technologie bien avant leurs concurrents.

La réaction des fabricants canadiens face à cette nouvelle concurrence préoccupe un grand nombre d'observateurs allant des ministères et organismes gouvernementaux aux syndicats. On craint que le Canada ne soit pas à la hauteur parce qu'il n'a pas investi dans la nouvelle technologie ni mis au point des techniques de gestion. Le but du présent rapport est d'explorer l'impact de la technologie sur la compétitivité de l'industrie canadienne de profilage du métal. Il compare le niveau de technologie utilisé dans les industries de profilage du métal du Canada, des États-Unis, du Japon et de l'Europe.

Aux fins du présent rapport, la définition de la technologie comprend :

- la technologie des matières premières
- la technologie de transformation et de fabrication
- la technologie de conception
- la recherche et le développement.

Cette définition tient également compte des facteurs suivants :

- o disponibilité et qualité des matières premières
- o conception et fabrication assistées par ordinateur
- o robotique et autres systèmes perfectionnés de fabrication et de manutention des matériaux
- o systèmes automatisés d'essais et de contrôles non destructifs
- o productivité, réduction des déchets et qualité du produit
- o recherche et développement
- o matériaux de rechange et procédés connexes.

L'objectif premier de l'étude a été de mesurer l'écart technologique existant entre l'industrie canadienne et l'industrie étrangère. À cette fin, nous avons cherché à déterminer les technologies nouvelles ou potentielles susceptibles de s'appliquer à l'industrie, à évaluer la capacité de l'industrie canadienne de les assimiler et à identifier des méthodes de transférer à l'industrie les nouvelles technologies résultant des travaux de recherche et de développement.

La gamme des technologies étudiées comprend :

- o technologie d'approvisionnement en matières, tenant compte des caractéristiques relatives à la métallurgie, aux dimensions et à la surface;

- o méthodes de préparation des matériaux telles que l'affinage et le chauffage;

- o technologie de manutention des matériaux, y compris l'utilisation de la robotique;

- o conception des matrices, y compris la FAO;

- o conception des presses;

- technologie de la microélectronique s'appliquant aux procédés de profilage du métal;
- opérations d'assemblage et de finition, y compris le traitement thermique;
- procédés d'essais et de contrôles non destructifs;
- pratiques de gestion susceptibles d'avoir une incidence sur la technologie de production;
- matériaux et procédés concurrentiels tels que les plastiques, les pièces de fonte et la métallurgie des poudres.

1.2 Méthodologie

Le présent rapport s'appuie sur les résultats de recherches menées vers la fin de 1983 et en 1984. La méthodologie utilisées est la suivante :

- analyse approfondie des données publiées concernant la production de produits et d'éléments finis;
- étude et analyse approfondées des publications concernant les nouveaux matériaux, procédés, méthodes et production et outillages;
- collecte et analyse des catalogues, bulletins et documents techniques publiés par les fournisseurs de matières premières, les fabricants et les fournisseurs de machinerie et d'outillage;

- nombreuses entrevues et visites d'usines avec des transformateurs de tôle, des compagnies de forgeage, des fournisseurs d'outillage ainsi que des fournisseurs de matières premières du Canada, des États-Unis, d'Europe et du Japon. Annexe A contient une liste complète des personnes consultées.

1.3 Structure du rapport

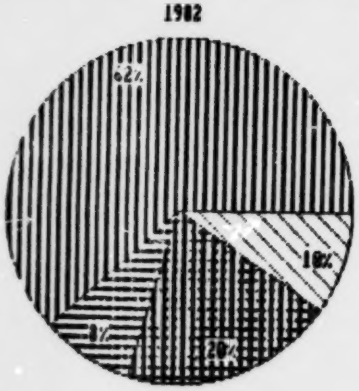
Le rapport se divise en 3 volumes. Le Condensé donne un aperçu du rapport principal. On y trouve les principaux résultats, conclusions et recommandations de l'étude sous des rubriques générales consacrées à l'industrie de profilage de la tôle et à l'industrie de forgeage.

Le Volume I du rapport principal porte sur l'industrie d'estampage et d'emboutissage et le Volume II, sur l'industrie de forgeage. Dans chaque volume, l'analyse découle de l'examen initial de la structure du marché. Suivant ensuite une série de chapitres consacrés à l'étude et à l'analyse de l'industrie, depuis les matières premières à l'inspection du produit fini. Les dernières parties de chaque volume donnent un aperçu détaillé des progrès technologiques et des besoins de l'industrie canadienne en matière de recherche, ainsi que du rôle de CANMET face à ces besoins.

Les nombreuses annexes qui sont jointes aux volumes I et II complètent l'analyse des questions soulevées dans le rapport principal.

TABLEAU 1

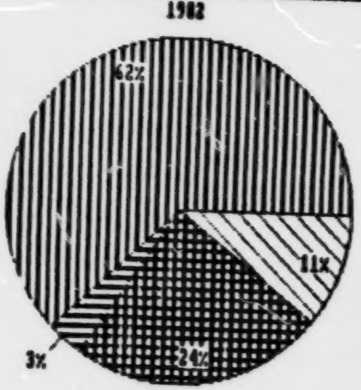
Coûts des industries de
l'estampage et de la forgeage



Forgeage Ferreaux

- ▥ Coût de matière première
- ▤ Coût de l'energie
- ▦ Main-d'oeuvre
- ▧ Main-d'oeuvre indirect

Coûts des industries de
l'estampage et de la forgeage

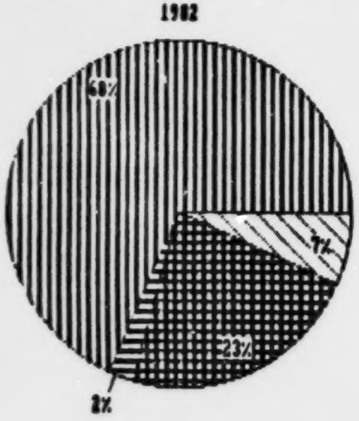


Divers

- ▥ Coût de matière première
- ▤ Coût de l'energie
- ▦ Main-d'oeuvre
- ▧ Main-d'oeuvre indirect

Total $1,411,573 M

Coûts des industries de
l'estampage et de la forgeage

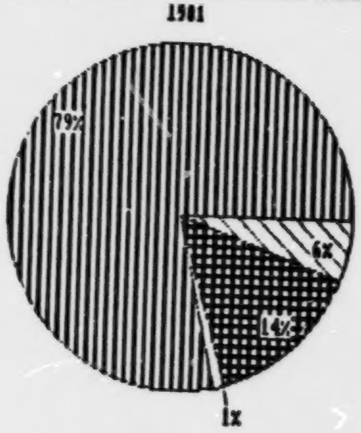


Pièces d'aûto

- ▥ Cout de matière première
- ▤ Coût de l'energie
- ▦ Main-d'oeuvre
- ▧ Main-d'oeuvre indirect

Total $5,059,731 M

Coûts des industries de
l'estampage et de la forgeage



Estampage

- ▥ Coût de matière première
- ☐ Coût de l'energie
- ▦ Main-d'oeuvre
- ▧ Main-d'oeuvre indirect

Total $3,398,405 M

Source: Statistics Canada

I - RÉSUMÉ ANALYTIQUE

Le présent rapport présente une évaluation et une comparaison des technologies utilisées dans les industries de profilage du métal et de forgeage de l'Amérique du Nord, du Japon et de l'Europe de l'Ouest. Il s'appuie sur des données premières et secondaires ainsi que sur un grand nombre de visites d'usines effectuées dans chacune des régions visées.

Pour analyser la technologie de l'industrie de profilage du métal et le rôle de la technologie dans la compétitivité de cette industrie, il est essentiel de bien comprendre deux éléments de la structure des coûts de l'industrie, soit :

a) l'importance du coût des matières premières
b) l'importance du rapport

$$\frac{\text{rendement utilisable}}{\text{capacité théorique}}$$

Le coût des matières premières constitue le principal élément du coût de fabrication dans les industries de profilage du métal. Il représente au moins 50% de la valeur de vente du produit de tôle ou forgé. Dans certains cas, le coût des matières représente plus de 80% du prix de vente d'un produit. Les coûts de la main-d'oeuvre et de l'énergie représentent un pourcentage beaucoup moins élevé du coût total. Généralement, le coût direct de la main-d'oeuvre est inférieur à 20 du coût total du produit. Quant au coût de l'énergie, il représente généralement moins de 10% du coût. Ces facteurs sont illustrés au tableau 1 relativement à divers éléments de l'industrie canadienne de profilage du métal. La répartition des coûts dans les autres pays comme les États-Unis, le Japon et l'Europe est sensiblement la même. La clé du succès de l'industrie de profilage du métal est donc l'accroissement ou la maximalisation du rendement d'une quantité donnée de matière première. Il existe plusieurs moyens d'atteindre ce but, dont les suivants :

- conception des matrices
- conception des procédés
- technologie des procédés

L'autre facteur-clé dont il faut tenir compte est le rendement du procédé qui renvoie au rapport :

$$\frac{\text{produit utilisable}}{\text{capacité théorique}}$$

et qui est déterminée par la formule suivante :

$$\begin{array}{ccccccccc} \text{capacité} & & \text{heures} & & \text{utilisation} & & (\text{1-taux}) & & \text{rendement} \\ \text{évaluée} & \times & \text{disponibles} & \times & \text{machine} & \times & (\text{ de }) & = & \text{du produit} \\ (\text{pièces/h}) & & & & (\text{h/année}) & & (\text{défaut}) & & \text{utilisable} \end{array}$$

Ainsi, la technologie et les procédures qui accroissent l'utilisation-machine et réduisent le taux de défaut peuvent avoir un impact considérable sur le coût final de fabrication d'un produit.

Tout au long du rapport, nous reviendrons sur ces deux éléments-clés de succès dans l'industrie de profilage du métal. L'interaction de ces facteurs avec divers éléments du produit, du procédé et de la technologie de la gestion est un des points importants du rapport.

Conclusions

Les principales conclusions de la recherche et de l'analyse sont les suivantes :

- L'industrie canadienne utilise une technologie similaire à celle utilisée par les compagnies américaines, européennes et japonaises.

- Les différences entre la technologie utilisée par l'industrie canadienne et celle des autres pays se situent davantage sur le plan de l'échelle que d'une méconnaissance de la technologie. Les tableaux 2 et 3 illustrent bien ces différences en indiquant la distribution des machines de profilage du métal dans les principaux pays industrialisés, en fonction de leur nombre et de leur âge.

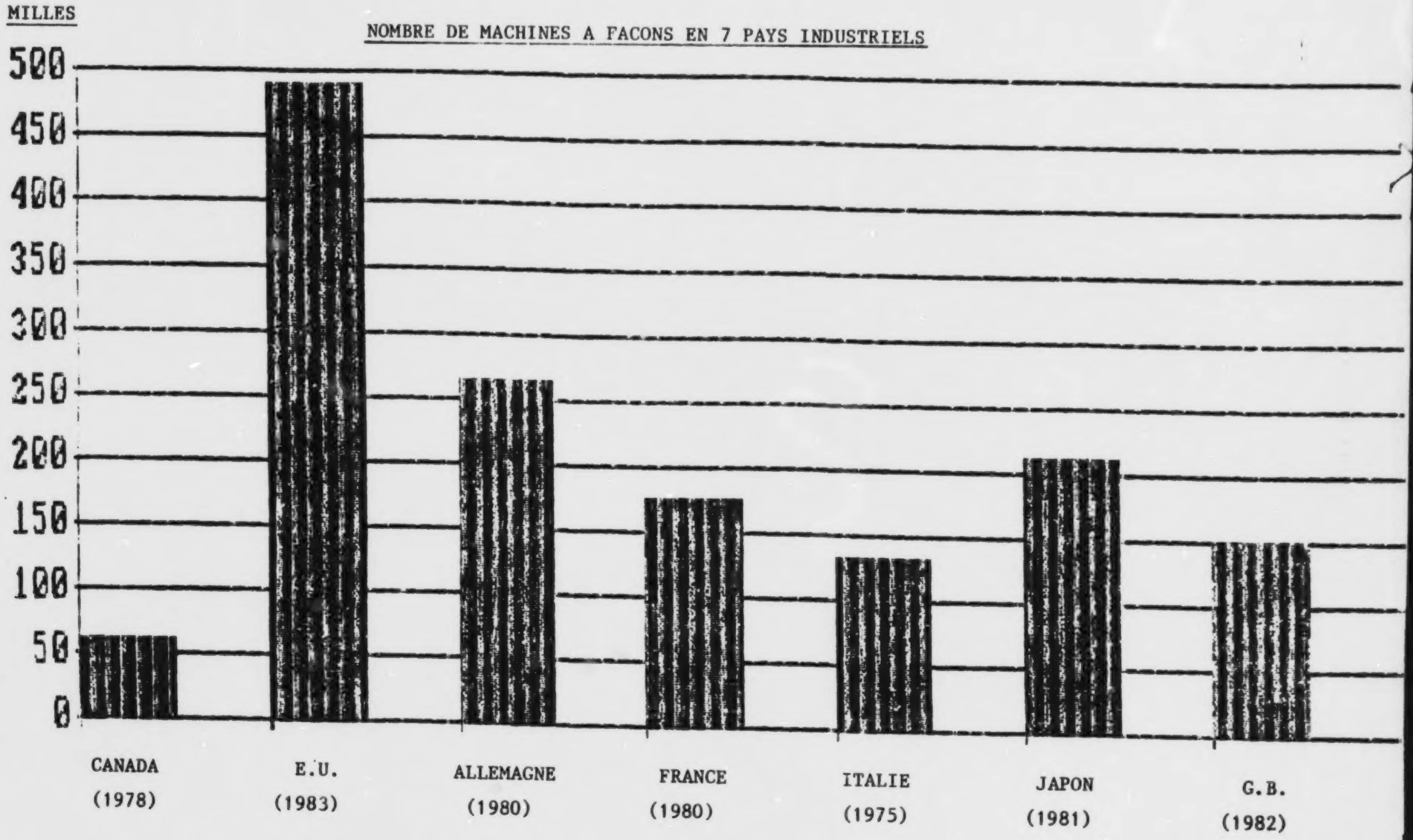
- Le niveau de connaissance du comportement du métal soumis à l'opération de profilage est généralement moins élevé en Amérique du Nord qu'au Japon.

- L'utilisation des technologies de fabrication de pointe comme la CAO/FAO, la robotique et l'outillage pour les essais et contrôles non destructifs est limitée aussi bien au Canada que dans les autres pays. Seules les grandes compagnies ont adopté ces technologies, les industries de automobile et de l'aérospaciale étant les plus perfectionnées.

- L'industrie nord-américaine de l'automobile est en passe d'adopter un système de haute technologie pour résoudre ses problèmes de productivité et de qualité, forçant ainsi les fournisseurs à emboîter le pas. Très peu de compagnies canadiennes sont équipées, sur les plans de la technique et de la gestion, pour s'adapter à cette rapide évolution.

- L'industrie canadienne peut accroître considérablement sa productivité en recourant à des techniques simples et éprouvées comme :
  - les procédures rapides de changement de matrices
  - l'utilisation de dispositifs simples de transfert
  - l'utilisation de procédures statistiques de contrôle des procédés
  - l'utilisation de la technologie de presse.

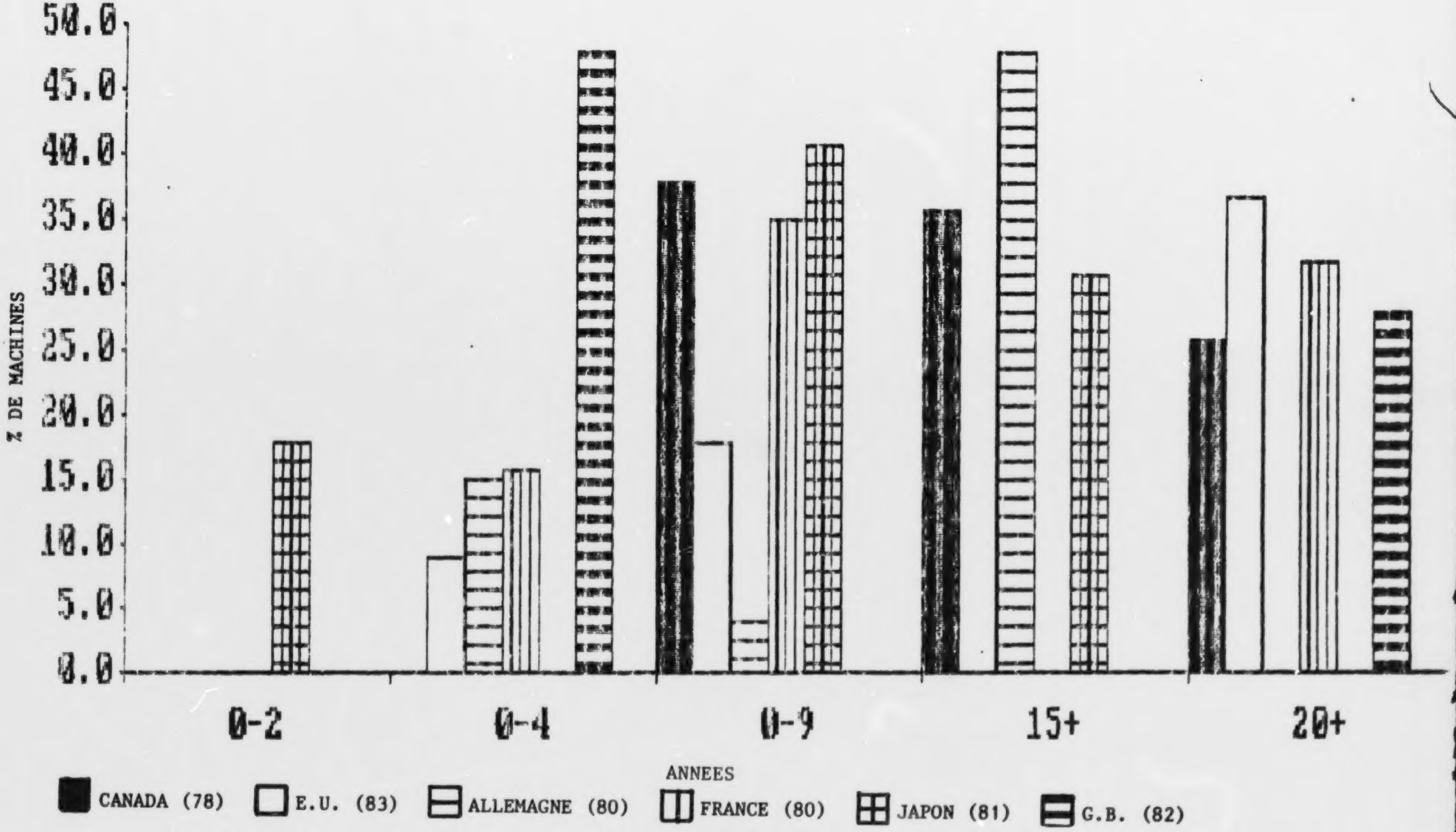
TABLEAU 2



NOMBRE DE MACHINES A FACONS EN 7 PAYS INDUSTRIELS

TABLEAU 3

AGE DE MACHINES A FACONS EN 6 PAYS INDUSTRIELS



- La position concurrentielle des Japonais est due en grande partie à une application poussée de ces techniques plutôt qu'à l'utilisation étendue de techniques hautement automatisées de conception, de production et d'assemblage.

- La qualité des matières premières produites au pays pour l'industrie canadienne de profilage du métal est considérée bonne et supérieure à celle des fournisseurs américains.

- Les fournisseurs européens semblent offrir des matières de même qualité que celles fournies par les usines américaines.

- Les producteurs japonais de métaux ferreux et non ferreux ont tendance à offrir des matériaux de meilleure qualité.

- Les taux moyens de rejet des matières premières sont les suivants :

Acier rejeté (pourcentage des achats)
(en fonction des tonnes produites)

	Tôle	Pièces de forge
Canada	1%	2%
États-Unis	2,5%	2.5%
Europe	1,5%	2,5%
Japon	0,5%	0,5%

- La qualité supérieure des matières premières japonaises aide les compagnies japonaises de profilage du métal à fabriquer plus efficacement des produits de qualité supérieure.

- Les taux de rejet en cours de procédé sont considérablement moins élevés au Japon que dans les autres pays étudiées. Cette qualité supérieure ne dépend pas de l'application de la nouvelle technologie, mais des efforts concertés de la direction et de la main-d'oeuvre (de la direction surtout) visant à mettre au point des méthodes efficaces de fabrication et à appliquer des procédures statistiques de contrôle des procédés à toutes les étapes de la fabrication, depuis les matières premières au produit fini.

Les taux de rejet moyens de l'industrie de profilage du métal sont :

	Tôle	Pièces de forge
Canada	2% - 3%	2% - 3%
États-Unis	2% - 3%	2% - 3%
Europe	0,5%	0,5%
Japon	2% - 5%	02% - 4%

- L'industrie canadienne de profilage du métal ne peut compter sur des sources intérieures d'approvisionnement en tôle et pièces de forge aussi importantes que l'industrie des autres pays. Cette pauvreté de l'approvisionnement intérieure est essentiellement due à la taille du marché et non pas à des facteurs d'ordre technique.

- L'industrie canadienne de profilage du métal effectue peu de travaux de recherche et de développement. Elle compte essentiellement sur les résultats des travaux effectués dans d'autres pays pour accroître ses connaissances du comportement du métal lors du profilage, de l'outillage et des procédés de production. En outre, elle ne fait à peu près pas appel aux organismes de recherche externes, aux universités et autres sources d'information des autres pays.

o L'industrie canadienne de profilage du métal affirme avoir besoin de plus amples informations sur les caractéristiques de profilage d'une vaste gamme de matières. Elle a surtout besoin de données détaillées sur :

- les aciers à haute résistance et faible alliage et les aciers à haute résistance;
- les aciers recuits au passage;
- les aciers pré-revêtus (galvanisés, pré-peints, aluminés);
- les aciers en coulée continue pour le forgeage;
- les aciers microalliés pour le forgeage;
- les aciers pour le forgeage à froid et à chaud;
- les matières composites;
- les matériaux non ferreux en feuille et en barre;
- les matières et les procédés pour la métallurgie des poudres.

o L'industrie canadienne de profilage du métal a besoin de programmes de conception assistée par ordinateur (CAO) incorporant l'analyse d'éléments finis qui permettraient l'examen du comportement des tôles et matériaux en barre soumis à l'opération de profilage ainsi que l'évaluation de méthodes de conception des matrices au moyen d'ordinateurs à 16 et 32 bits.

Les programmes en place sont trop généraux et ne conviennent pas à l'industrie de profilage du métal.

II - INDUSTRY STRUCTURE

This chapter describes and analyzes the market structure and size of the metalforming industries of Canada, the United States, Japan, and Europe. The analysis is based on published data. Limitations on the availability of data prevent a detailed discussion of the various subsectors of the sheet metalforming and forging industries in each region of interest.

2.1 Stamping and Pressing Industries

2.1.1 Canada

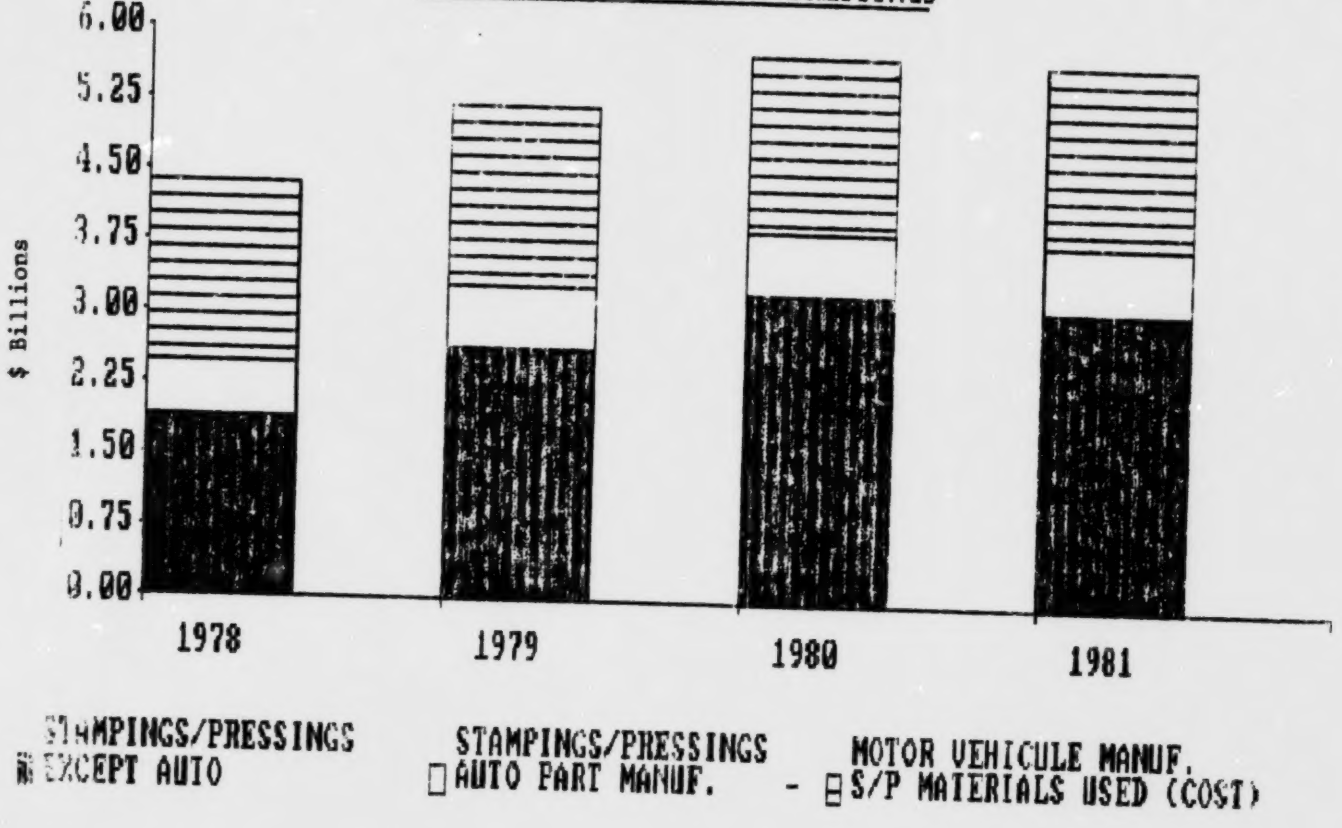
The stamping and pressing industry is comprised of a diverse range of manufacturers producing parts, assemblies, and finished products on both a captive and non-captive basis. The principal sheet metalforming industries are:

- automotive vehicles and parts;
- electrical and electronic machinery and equipment, including domestic appliances;
- non-electrical machinery industries such as agricultural and construction equipment;
- containers and packaging such as cans and drums;
- miscellaneous fabricated metal products such as housewares, metal furniture, roll formed metal products, etc.

Because of the diversity of end-use markets, reliable data on production volumes of the sheet metalforming industry is not available for Canada, nor for any other country. Exhibit 2.1 provides some data on the magnitude of the industry in Canada.

EXHIBIT 2.1

CANADIAN STAMPINGS AND PRESSINGS



The stamping and pressing industry around the world is characterized by small plants. Few Canadian companies have more than 100 employees, with most companies employing between 20 and 100 employees. These factors are illustrated in Exhibit 2.2 in terms of Canada. A similar distribution of plants by employee size is to be found in the United States, Japan, and Europe.

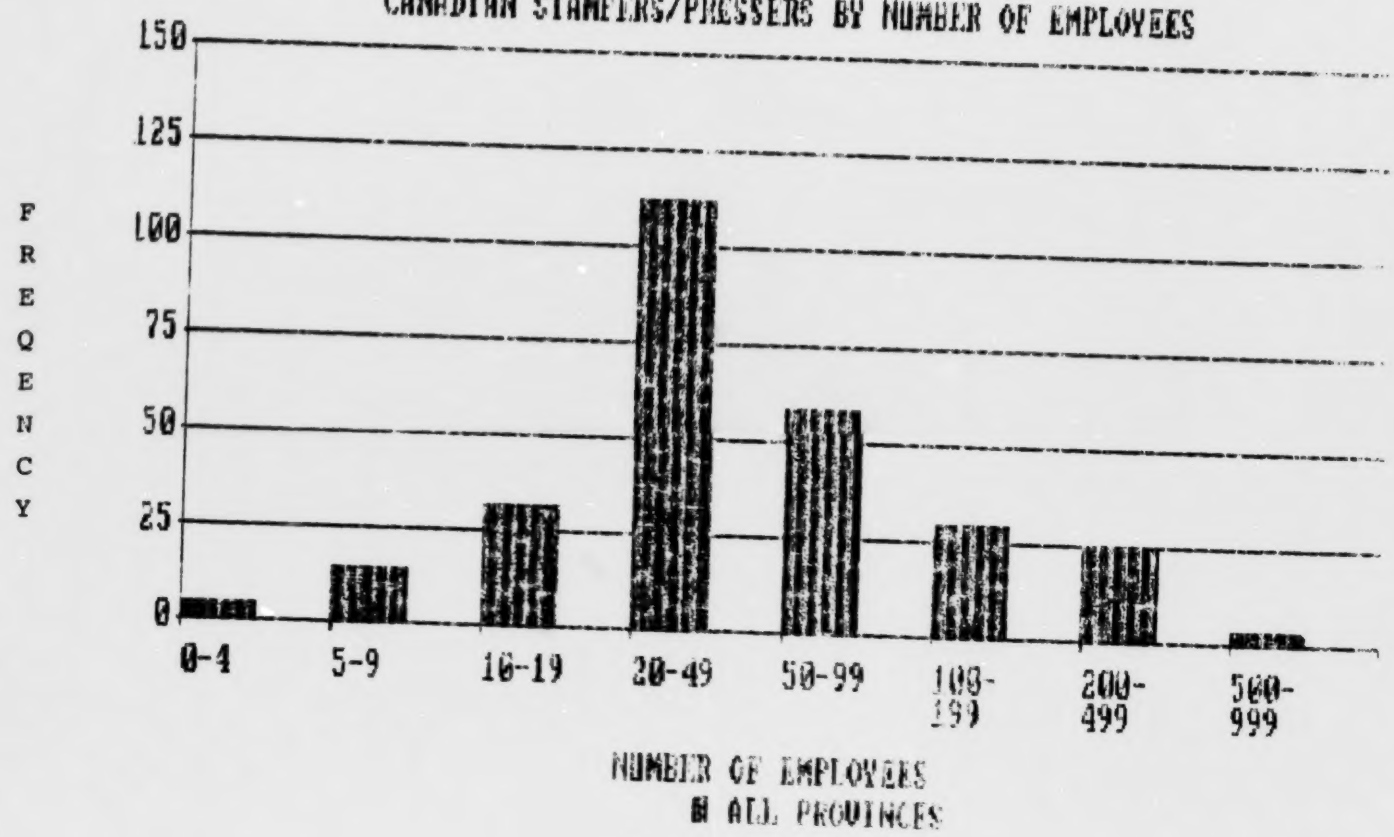
The large number of small plants in the industry has a significant impact on its technological capability in terms of:

- production management skills;
- technological skills such as knowledge of the forming behaviour of metals and of forming machinery;
- ability to invest in modern plant and equipment.

These weaknesses are more pronounced in Canada than in other locations due to the low level of secondary manufacturing relative to that in other countries. The secondary manufacturing industry in Canada, more so than in other countries, is subject to short production runs of a wide variety of parts. This has a distinct impact on productivity and material utilization. In general, the Canadian stamping and pressing industry has a poorer productivity record than its competitors in the United States, Europe, and Japan. Solutions to the problems caused by short production runs are available, and have been applied successfully across a broad range of manufacturers. These solutions have both a technological base, such as the use of quick die change tooling; and a management base, such as the organization of production into work cells. The Japanese have been highly successfuly in applying these techniques, and have achieved significant productivity improvements as a result. These points will be elaborated on in subsequent sections of the report.

On a country-by-country basis, we can note the following similarities and differences between the stamping and pressing industry in Canada and elsewhere:

EXHIBIT 2.2


CANADIAN STAMPERS/PRESSERS BY NUMBER OF EMPLOYEES

2.1.2 United States

The diversity of manufacturing plants in the United States, and the consequent diversity of stamping operations, makes direct comparisons between the Canadian industry and the United States industry difficult. However, the following observations can be made:

- the smaller U.S. companies tend to have similar problems with technology, production management and capitalization as do Canadian plants;
- larger U.S. plants, while generally employing similar technology to comparable Canadian plants, tend to have a better understanding of metal deformation and are somewhat better organized as regards production flow and management;
- batch sizes tend to be significantly larger in U.S. plants than in Canadian plants, reducing the necessity for manufacturing flexibility;
- steel distributors are more important in the United States than in Canada.

2.1.3 Japan

Several characteristics of the Japanese stamping industry are important to bear in mind when discussing its technology. These factors, while principally relating to the automotive stamping industry, are generally true for other sectors of the industry. The factors are:

- relationships between supplier and customer are very strong, and contribute to manufacuring efficiency in a number of ways. The major automobile manufacturers each have a network of suppliers and often hold equity in these companies;

- the general level of technical knowledge of metalforming behaviour and metalforming processes and technology is quite high, even for production line workers;
- the industry emphasizes the production of assemblies rather than parts, thus achieving a higher value added than is typical in North America;
- the industry is characterized by very efficient use of both traditional technologies and advanced technology;
- the industry has a significant investment in both machinery and training of production staff, relative to the size of individual companies;
- production contracts from the automobile manufacturers are long term, often contain product design and testing requirements, and always include demanding specifications with regard to quality, delivery, and price. These requirements stimulate attention to production management efficiencies;
- the Japanese automotive industry buys approximately 70 to 80% of its stamping requirements from outside vendors. In contrast, the North American industry generally sources less than 50% of its parts' requirements from outside vendors;
- stamping plants are located in close proximity to assembly plants, promoting frequent deliveries of parts to the assemblers.

2.1.4 Europe

The automobile and aerospace industries have a significant impact on the stamping and pressing industry in Europe. In general, where the automobile and aerospace industries are strong, the supporting stamping and pressing industry is strong and employs relatively modern technology. Those companies serving other industries tend to be less well managed, technologically weaker, and less adaptable to changes in the marketplace.

On a country-by-country basis, we note the following:

2.1.4.1 Sweden

- Vigorous automotive industry with two major manufacturers, Volvo and Saab.
- Active aerospace industry producing civil and military aircraft (Saab).
- Large domestic appliance industry (Electrolux and Husqvarna).
- Vigorous machinery industry producing both electrical and non-electrical machinery.

2.1.4.2 West Germany

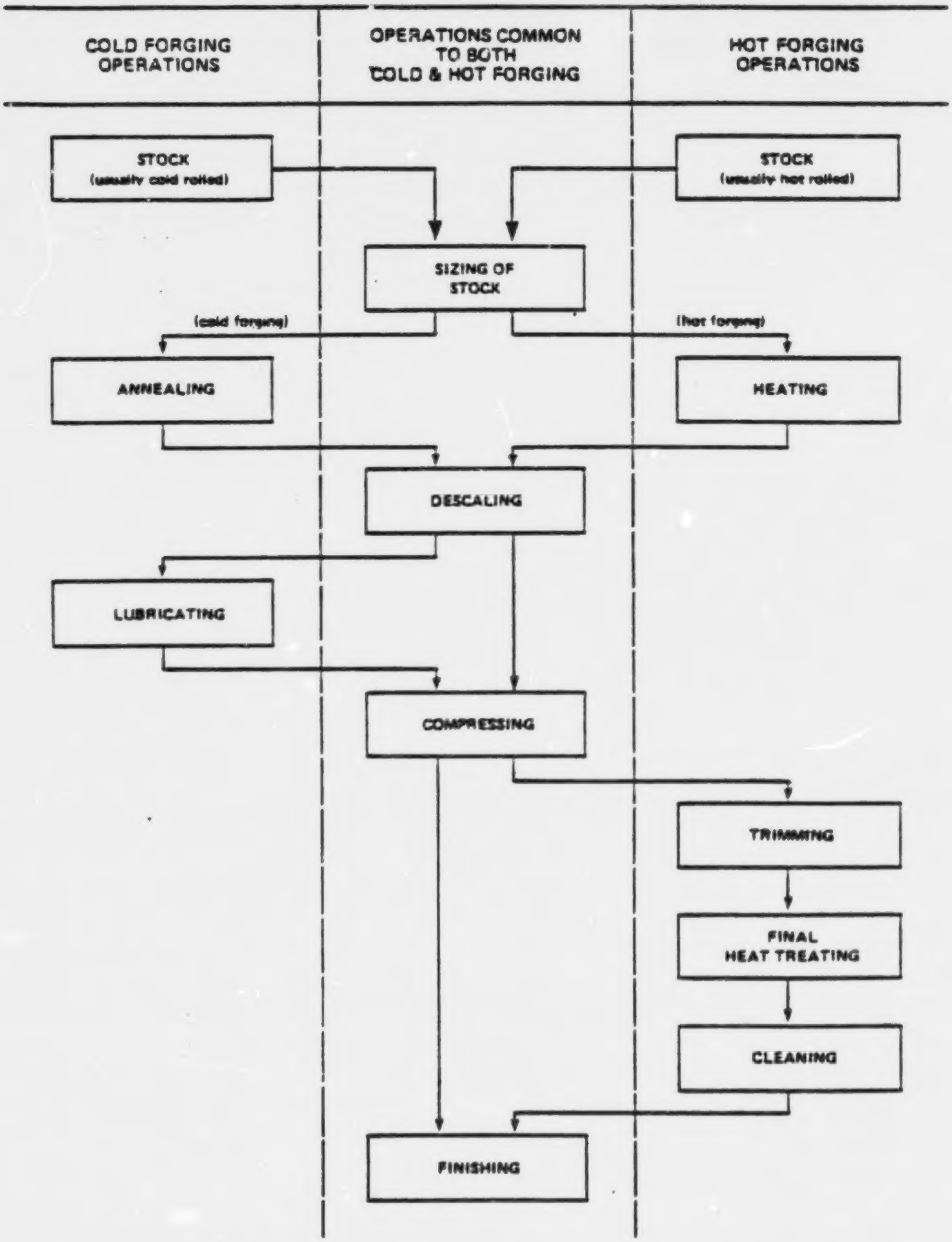
- Large and vigorous automotive industry with worldwide capabilities.
- Modern, research oriented machinery industry.
- Large domestic appliance industry.

2.1.4.3 France

- Large automotive industry, much of it state owned.
- Large civil and defense aerospace industry.
- Large domestic appliance industry.

EXHIBIT 2.3

OVERVIEW OF FORGING OPERATIONS



2.1.4.4 United Kingdom

- Automotive industry has been in decline, as has aerospace industry.
- Relatively modern domestic appliance industry.
- Machinery industry has been in decline.

2.2 Forging Industry

The forging industry is comprised of those companies which bulk form metal by means of compression between a set of dies. This is accomplished by means of hammering, pressing, rolling, or upsetting. Forging operations may take place either in the hot state, or using either warm or cold metal. The choice of working temperature depends on the nature of the material being formed. The nature of the part being made, and the desired physical and mechanical properties.

The forging process confers a number of enhanced mechanical and physical properties on the raw material being worked. These properties result from:

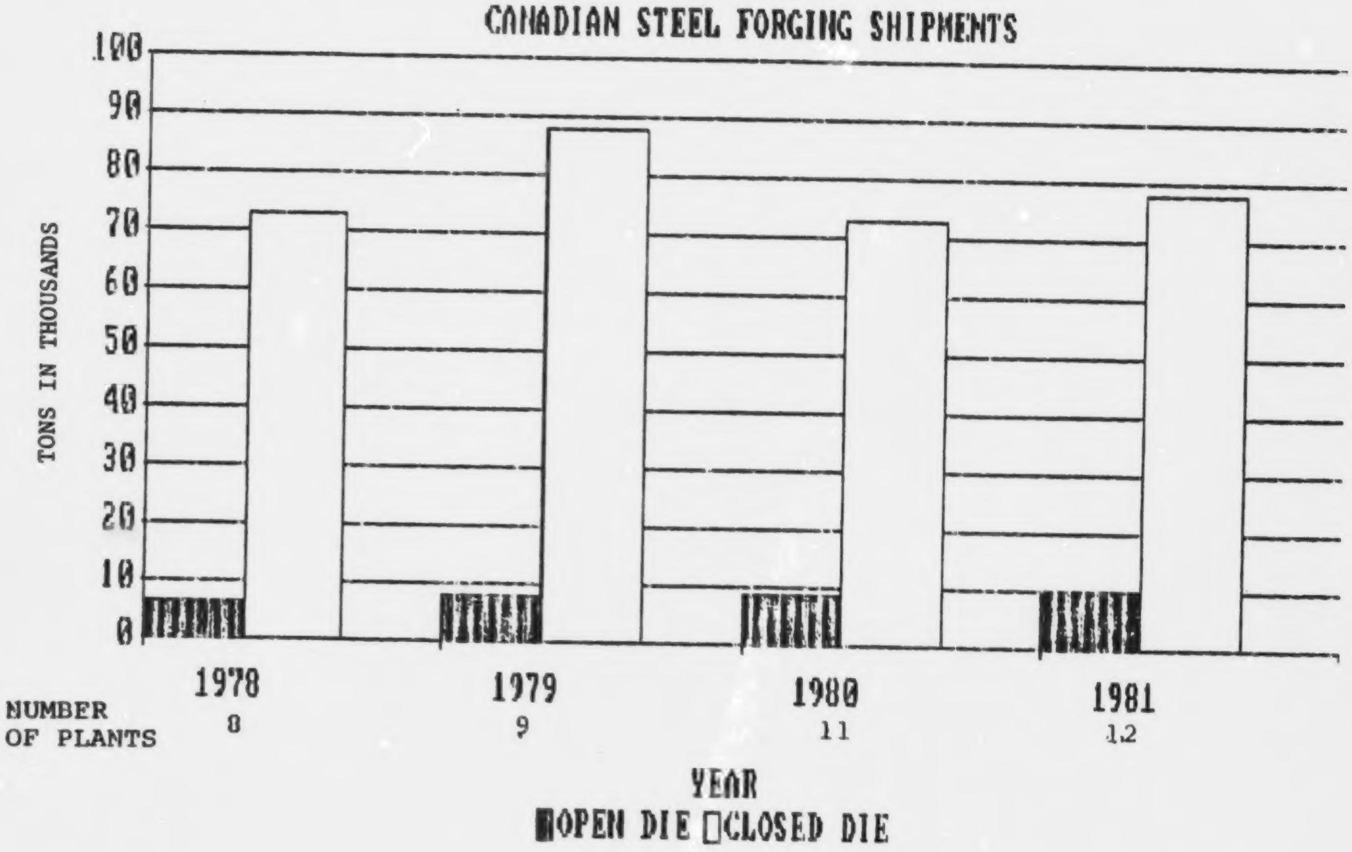
- consolidation of internal voids
- flow patterns of the crystal grains
- uniformity of grain size
- better response to quench and temper heat treatment (hot forging only)
- work hardening (cold forging only)

An overview of forging operations is shown in Exhibit 2.3.

The forging industry differs from the stamping and pressing industry in one key regard -- the production of finished parts. In general, the forging industry does not produce finished components, as does the stamping and pressing industry. Most forgings require a considerable amount of additional processing before they can be used as finished parts. Because of this, the industry does not exhibit the same diversity of operations as the stamping and pressing industry.

EXHIBIT 2.4

CUSTOM FORGING PLANTS



Source: Statistics Canada

The forging industry is dominated by the transportation equipment industry. In Canada, approximately 80% of forgings by weight are destined for the railroad equipment, automotive, form machinery, and off highway equipment markets. A similar pattern is exhibited by the forging industries of the United States, Japan, and western Europe, although aerospace components play a significant part in the U.S. market. Data on the size of the Canadian forging industry is provided in Exhibit 2.4.

On a country-by-country basis, the following is noted with respect to the structure of the forging industry.

2.2.1 Canada

The Canadian forging industry is very small in comparison with other countries. The industry is comprised of:

- seven open die forging plants, one of which is mainly for captive operations and six others which are primarily commercial;
- twenty impression die ferrous forging plants, of which four are totally captive operations and six others are primarily captive;
- four non-ferrous forging plants, of which one specializes in aluminum forgings for aircraft use;
- six major manufacturers of fasteners such as bolts.

The industry is concentrated in Ontario, especially in the vicinity of St. Catharines, due to the proximity of the steel mills. Other major centres of forging activity are Montreal, Winnipeg, Windsor, and Calgary. Statistical data on the Canadian forging industry is difficult to obtain. Much of the industry is classified by product end-use rather than manufacturing process. This is especially true for those companies producing hand tools, automobile parts, and fasteners. For example, the General

Motors forge plant in St. Catharines is classified as a manufacturer of automobile parts rather than as a forging plant. This plant is a major producer of forgings for the automotive industry, and the lack of data on its production severely distorts the available data.

The most complete data on the Canadian impression die ferrous forging industry is to be found in a 1979 survey conducted by the Department of Industry, Trade, and Commerce. This survey provided the following basic data:

. Ownership (based on monthly capacity)	
- private, Canadian owned	14.1%
- Canadian owned subsidiary	36.8%
- foreign owned subsidiary	49.0%
. Monthly production capacity	32,595 tons
- of which, jobbing	15,353 tons
- of which, captive	17,142 tons
. Employment Size	
- less than 50 employees	5 companies
- 50 to 99 employees	3 companies
- 100 to 199 employees	7 companies
- over 200 employees	4 companies.

The situation in 1984 would not be much different in terms of ownership structure or production capacity. Employment structure would show some change to smaller companies due to a decline in industry shipments.

The Canadian ferrous forging industry predominantly works with low carbon steels. The 1980 report on the industry provided the following data with respect to type of material used:

DISTRIBUTION OF FERROUS FORGERS BY MATERIAL FORGED

NUMBER OF IMPRESSION DIE FORGING COMPANIES

MATERIAL USED	PERCENT OF TOTAL PRODUCTION				AVERAGE
	Under 25%	25% to 50%	50.1% to 75%	Over 75%	
Carbon Steel	2	3	6	8	67.1%
Low Alloy	12	6	1	-	22.4%
High Alloy	19	-	-	-	10.5%

The Canadian ferrous forging industry has a limited capacity to produce large forgings. The largest **hammer in** use in Canada is 15,000 pounds, while the largest mechanical press for impression die forgings is 4,000 tons. One company has a 6,000 ton hydraulic press used for the manufacture of railway wheels. As a consequence of this equipment limitation, impression die forgings in excess of 125 kg. are rarely produced. Open die forgings to a maximum of 125 kg. are rarely produced. Open die forgings to a maximum size of approximately 22,500 kg. can be produced in Canada.

2.2.2 United States

The United States has a large and very diverse forging industry. There are approximately 300 plants producing custom impression die forgings. Captive operations, esepcially those of the automotive, aerospace, and construction equipment industries also represent a substantial volume of production. Open die forging operations are more limited, but still represent a reasonable number of operations. In total, there are approximately 600 forging plants in the United States. Of these, approximately 375 would be considered to be modern, viable facilities. The balance are very small shops more akin to blacksmith shops, or are small captive operations with only one or two pieces of forging equipment.

The forging industry is concentrated in the north-eastern United States, especially in such centres as Cleveland, Toledo, Detroit, Lansing and Pittsburgh. These are major steel and/or automotive manufacturing centres and are also home to a wide variety of service shops such as tool and die makers, machine shops, heat treaters, etc. There is some concentration of aluminum forging plants on the west coast, due to the influence of the aircraft industry.

United States forging shops are generally of small size. Approximately 36% of the industry is represented by shops with fewer than 25 employees, and almost 60% of the industry is represented by plants with fewer than 50 employees. These smaller plants generally operate with old and inefficient equipment, and are likely to lose business to larger, more modern and efficient facilities.

2.2.3 Japan

The Japanese forging industry is characterized by two distinct groups. These are:

1) the major integrated steel producers, which produce large open die forgings for the shipbuilding and capital equipment industries. These companies also produce impression die forgings.

2) the small forging companies which produce impression die forgings for the automotive, farm machinery, hand tool, and other industries. A large number of the impression die forging companies are controlled by the major automotive manufacturers.

The forging industry in Japan is concentrated in two main regions. These are the Tokyo industrial area (Kanto) and the Osaka industrial area (Kansai). In the Kanto region, approximately 60% of the raw material for forging is supplied by the customer, while in Kansai region, customers supply approximately 40% of the raw material to be forged.

The major integrated forging companies generally have modern, highly efficient melting and degassing equipment to produce very high purity ingots for production of large open die forgings. The non-integrated forge shops are much more numerous and concentrate on production of forgings for the automotive and construction equipment industries. The non-integrated sector of the industry produces approximately twice the tonnage of forgings of the integrated sector.

2.2.4 Europe

The European forging industry is extremely diverse. It is comprised of small family-owned firms, some of which are technically advanced; medium sized firms producing a wide range of forgings; and very large firms, often comprising several plants which produce forgings ranging from simple parts to very complex aerospace components. The European industry tends to be more vertically integrated than the North American industry, at least in terms of raw material supply. The European industry also exhibits a generally higher level of technological "know-how" than does the industry in North America, and perhaps Japan. This technological superiority is partially due to the large number of forging machinery builders in Europe, who have been responsible for most of the recent advances, and also due to a much greater exchange of information within the European industry.

On a country-by-country basis, we can note the following characteristics regarding the size and structure of the forging industry.

2.2.4.1 Sweden

The Swedish forging industry is comprised of eighteen companies, including captive forge operations in Volvo.

Most of the forging companies in Sweden are small shops, with from 25 to 50 employees. Two companies in Sweden (Bofors and SKF) have their own steelmaking operations; while a third (Presmetall) is a subsidiary of Granges Aluminum. Other general characteristics of the Swedish forging industry that should be noted are:

- plant design is well laid out for good materials flow;
- forging, die making and heat treating equipment is generally very modern;
- the forging industry undertakes a higher portion of finish machining than is general for the industry in other regions;

- there is a close working relationship between the industry and the major research establishments.

2.2.4.2 Germany

The German forging industry is comprised of a large number (approximately 260) of small plants and a few very large plants controlled by steel companies or the automobile manufacturers. The ferrous forging industry in Germany produced approximately 1.14 million tons in 1980, and 1.20 million tons in 1981. Shipments by independent forge plants amounted to approximately 715,000 tons of steel forgings in 1981. The balance of shipments was accounted for by captive plants.

The German forging industry is more heavily oriented to the automotive industry than the forging industry in other countries. For example, in 1981, approximately 44% of ferrous forgings were directly consumed by the automotive industry, while an additional 20% went to the automotive parts industry.

2.2.-.3 France

The French forging industry is divided into two major segments. These are the captive forge operations of the major motor vehicle manufacturers, and the custom forging industry. The captive industry is modern and highly automated, and is equal in size to the custom forging industry. As a consequence, much of the custom forging industry has a struggle to survive. The industry has suffered a significant decline in shipments over the past few years. Most of the decline in shipments is attributable to a decline in shipments to the motor vehicle industry.

The French forging industry is comprised of the following number of plants:

- 87 plants with impression die forging operations, mainly drop hammer;

- 31 plants with open die operations, including those with their own steel production;

- 5 cold extrusion companies;

- 9 light alloy (aluminum and magnesium forging plants);

- 10 plants forging pole line hardware and fittings.

Most of the plants are located in the traditional steel making areas of the Ardennes, Loire, and the North. French forging companies have equipment up to 65,000 tons, the largest in the non-communist world.

2.2.4.- United Kingdom

The United Kingdom forging industry is comprised of approximately 75 companies. These companies are however, generally part of a group of companies. The major groups involved in the United Kingdom forging industry are:

- GKN (approximately 50% of the total U.K. forging industry);

- Inco Alloy Products Ltd. (Specializes in high temperature alloys and large automotive forgings.)

- Duport

- J. & H.B. Jackson Group.

The United Kingdom forging industry has been in decline for some time, especially that part of the industry oriented to general purpose ferrous forgings. The decline in production is attributable mainly to a decline in motor vehicle production in the United Kingdom, although other end-use industries have also suffered.

The United Kingdom forging industry is concentrated in the Midlands and North Midlands areas, especially the areas around Birmingham and Sheffield. Several of the major forging companies are associated with their own steel making or non-ferrous ingot production plants.

III - RAW MATERIALS

The basic raw materials of the metalforming industries are ferrous and non-ferrous sheet, coil, and bar stock. These materials are available in a very wide range of sizes, thicknesses, alloys, surface finishes, physical and mechanical properties. It is beyond the scope of this report to analyze all of these factors. Rather, this chapter of the report provides an analysis of the concerns of the metalforming industry in each region of interest regarding the general availability and quality of raw material stock.

3.1 Sheet Metal Supply

3.1.1 Ferrous

Canada

The supply of flat rolled products to the metalforming industry is generally considered to be adequate in all the regions under study. In almost all cases, supply capability is related more to the market demand for particular alloys, sizes, finishes, etc., than it is to deficiencies in the productive capability of the domestic industry. Because of this factor, smaller countries such as Canada, which are large exporters of flat rolled ferrous and non-ferrous products, are often large importers of the more specialized products.

There are, however, also technical restrictions on the range of product available from domestic mills. In the case of Canada, the principal restrictions are:

. low levels of utilization of technologies such as calcium addition, aluminum wire injection, electromagnetic stirring, ladle refining, and continuous casting to improve the quality and yield of carbon steels;

EXHIBIT 3.2

CANADIAN FLAT ROLLED STEEL AVAILABILITY

MAJOR PRODUCERS

	Hot Rolled Carbon	Cold Rolled Carbon	Hot Rolled HSLA	Cold Rolled HSLA	Hot Dipped Galvanized	Minimized Spangle Galvanized	Zincrometal	Galvalume	Aluminized	Prepainted	Electrolytic Tin Plate	Long Terne	Vitreous Enamalling	Electrolytic Chromium Coated	Electrical Steels	Tin Mill Black Plate	Rephos, Renitro Steels	Stainless
ALGOMA	X	X	X	X														
DOFASCO	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	
STELCO	X	X	X	X	X	X	X			X	X	X				X	X	
SIDBEC	X	X																
ATLAS																		X

Source: Company literature

- limitations on rolling capability in terms of width and gauge;
- lack of continuous annealing capacity in Canada;
- lack of electrogalvanizing capacity in Canada.

The Canadian steel mills are actively examining their technological posture to ensure they will be able to meet the expanded demands of the market. For example, Dofasco has announced it is examining the feasibility of installing electrogalvanizing and continuous annealing capacity to meet the requirements of the automotive industry. Dofasco and Stelco are currently examining the feasibility of installing additional continuous casting capacity for slabs. All of the major steel companies are conducting active programs to improve sensor technology, both in their iron and steelmaking operations and in the finishing operations. In several cases, Canadian mills have entered into technology agreements with Japanese steel companies to assist in these improvements.

Exhibit 3.1 provides information on the range of product available from the three major Canadian steel mills. The data indicate Canadian mills are able to supply products in most of the grades, sizes, and finishes in use in North America. However, not all of the mills produce the full product range. Thus, there is a limitation as to the competitive sources of supply. For example, Dofasco is the only domestic producer of electrical steels and of "Galvalume". Algoma does not produce coated steels. Stelco is the only Canadian producer of "Zincrometal". Atlas Steels is the only domestic producer of stainless steels.

Canada is a significant net exporter of flat rolled steel products, with exports generally exceeding imports by a ratio of 2:1. Canada's favourable export position is due to a variety of factors, chief of which are:

- modern, low cost plants, especially in comparison to U.S. steel mills;

- lower energy and labour costs than other countries, especially the U.S.

- a favourable exchange rate for the Canadian dollar in comparison to the U.S. dollar.

Imports of steel relate principally to those products for which the limited demand in Canada makes it uneconomic to produce. There are, however, also some general production deficiencies in the domestic steel industry. These product gaps are:

- continuously annealed HSLA
- electrogalvanized steels
- hot rolled carbon steel and HSLA coils wider than 2439 mm
- cold rolled carbon steel and HSLA coils wider than 1880 mm
- galvanized steel in coils wider than 1524 mm
- one-sided galvanized
- stainless steel sheet wider than 1219 mm.

These steels also happen to be the steels experiencing the most significant increase in demand. As previously noted, the domestic mills, especially Dofasco and Stelco, have announced plans to conduct technical and market studies regarding the feasibility of producing a broader product range in Canada.

United States

The U.S. steel industry is undergoing a period of rapid change. Since 1977 there have been substantial reductions in raw steel capacity on the part of the major integrated producers. These reductions have amounted to some 30 million tons. At the same time, non-integrated "mini-mills" have increased their capacity by approximately 20 million tons. The mini-mills, relying on electric furnaces and scrap as feed, have concentrated on production of low value-added products such as deformed bar. There is a trend, however, for these mills to be upgrading their production capability to produce more value products such as specialty bar and even sheet. For their part, the major integrated producers have undertaken a substantial upgrading program to install more continuous casting capacity and broaden their capacity for sheet by installing facilities for continuous annealing, electrolytic galvanizing, and other treatment methods.

The supply of sheet steel from domestic producers has generally been considered to be adequate. However, changes in the design of products such as automobiles and appliances are having an impact on the domestic capability to supply certain grades. For example, the automotive industry has significantly expanded its use of 2-sided and 1-1/2 sided electrogalvanized steel. This has put severe pressure on the domestic mills, which have been operating at capacity for these grades. Other grades also experiencing supply pressures are Zincrometal, Galvalume, and certain grades of HSLA. Consumption of Zincrometal, a coil coated corrosion resistant steel, was 850,000 tons in 1982. This matched the domestic production capacity for the product. Similar limitations on productive capacity are to be found for continuously annealed high strength, low alloy sheet for automotive use. Current capacity for this product is approximately 1 million tons, which matches the demand from industry.

The United States is a substantial importer of flat rolled steel. The major sources are Canada, Japan, and the European Economic Community. Net imports of flat rolled products amounted to over 7 million tons in 1983. This represented approximately 18% of domestic shipments, or 15% of total consumption of flat rolled products in 1983. Galvanized and other coated products represented 30% of imports in 1983.

Japan

The Japanese sheet industry is now the largest in the non-communist world. It is also the acknowledged leader in cost and quality. Exhibits 3.2 provides data on the production and disposition of Japanese steel.

The Japanese steel industry is now very oriented to product development and is able to offer its customers grades of steels not available from other sources. This capability has given the Japanese metalforming industry the opportunity to explore design and manufacturing options not available to the metalforming industries of other countries.

EXHIBIT 3.2

JAPANESE STEEL PRODUCTION/CONSUMPTION

Production of Hot

Year	Semis (1)	Rails & Accessories	Sheet Pilings	Shapes (2)	Bars	Rounds for Tubes	Wire Rods
1973	86,729	583	1,386	10,334	10,974	1,580	6,023
1974	87,544	486	724	8,705	10,443	1,670	6,164
1975	79,226	546	918	7,799	8,923	1,421	5,208
1976	83,126	377	875	8,822	9,699	1,468	5,976
1977	79,464	590	1,067	7,330	9,356	1,765	5,367
1978	78,258	640	1,260	7,386	10,580	2,270	5,241
1979	87,846	548	1,313	8,759	13,761	2,427	5,273
1980	87,357	504	1,266	9,160	13,402	2,682	5,318
1981	78,884	439	1,124	9,042	11,409	2,632	4,082
1982	77,868	500	1,097	8,936	12,209	2,399	3,704
1983	77,210	442	787	8,637	12,582	2,187	4,293

Rolled Ordinary Steel

1,000 Metric Tons

Heavy Plates ≥6%	Medium Plates 3%≥ <6%	Sheets <3% (4)	Wide Strip ≥500%	Strip & Hoops <500%	Tyres & Wheels	Sub Total	Re-rolled Steel	Total	Year
16,046	1,803	867	39,173	2,183	148	91,040	1,534	92,574	1973
17,588	1,691	636	39,365	1,629	159	89,588	1,481	91,039	1974
14,251	1,304	528	32,376	1,390	183	76,812	1,067	77,879	1975
12,614	1,564	601	38,266	1,698	116	82,068	1,090	83,161	1976
11,187	1,567	686	37,861	1,719	98	78,592	1,024	79,617	1977
9,566	1,599	740	37,395	1,673	88	78,434	1,191	79,625	1978
10,020	1,500	822	41,446	1,787	96	87,751	1,324	89,075	1979
10,989	1,140	696	40,738	1,714	104	87,694	1,195	88,888	1980
10,501	893	447	36,958	1,279	74	78,877	920	79,797	1981
9,432	900	459	36,390	1,177	65	77,277	929	78,206	1982
8,205	1,209	419	36,642	1,101	86	76,590	962	77,552	1983

Production of Cold Rolled, Coated Ordinary

Year	Cold-Finished Hoop	Cold-Wide Strip (≥500%)	Cold-Rolled Sheets	Cold Electrical Sheets & Strip	Tin Plate	Galv. Sheet	Other Metallic Coated Sheets	Cold-Formed Shapes
1973	316	14,826	3,481	1,078	1,986	5,378	726	1,751
1974	299	14,742	3,236	1,088	2,017	5,301	722	1,312
1975	192	13,057	2,420	630	1,559	4,307	598	1,043
1976	245	17,193	3,030	1,076	1,797	5,824	769	1,131
1977	229	17,099	3,012	1,023	1,866	5,904	917	1,028
1978	214	16,835	2,629	1,142	1,810	5,915	969	1,148
1979	218	18,913	2,208	1,102	1,884	6,897	1,142	1,230
1980	231	19,156	2,118	1,028	1,849	6,899	1,170	1,081
1981	218	17,561	2,038	938	1,666	6,220	1,131	826
1982	213	17,442	2,068	1,038	1,638	6,600	1,219	846
1983	228	18,589	2,225	1,186	1,588	7,169	1,497	842

Steel Products, Ordinary Steel Pipes & Cast Iron Pipes

1,000 Metric Tons

Cold-Finished Bars	Uncoated Wires	Hard Wires	Seamless Pipes	Elec. Welded Pipes	Butt-Welded Pipes	Arc-Welded Pipes	Cast Iron Pipes	Year
701	2,452	920	1,396	4,161	1,558	1,688	809	1973
624	2,195	873	1,418	4,146	1,378	1,611	825	1974
448	1,691	673	1,321	3,410	818	2,278	575	1975
529	1,808	734	1,374	3,589	868	1,590	685	1976
436	1,520	739	1,580	3,987	871	1,560	709	1977
434	1,292	782	1,879	4,039	833	1,857	764	1978
430	1,208	808	1,910	4,778	1,108	1,814	840	1979
443	1,121	795	1,919	4,680	1,078	1,923	848	1980
395	1,016	698	1,888	4,829	902	2,080	796	1981
367	1,121	692	1,818	4,296	739	1,777	911	1982
371	1,101	703	1,736	3,631	592	1,412	912	1983

Order Booked of Ordinary

Year	Construction & Repairing	Industrial Machinery & Equipment	Electrical Machinery & Equipment	Home & Office Appliances	Shipbuilding & Marine Equipment	Automobiles	Rolling Stocks
1973	18,011	2,462	2,082	772	6,514	6,102	179
1974	13,876	2,482	1,782	677	7,323	5,882	176
1975	11,184	1,689	1,300	566	6,377	5,458	98
1976	10,654	1,702	1,877	694	4,847	6,481	118
1977	11,317	1,614	1,692	620	3,831	6,560	111
1978	13,296	1,876	2,032	563	2,358	7,262	117
1979	15,283	2,214	2,460	724	2,924	8,543	117
1980	14,846	2,435	2,524	752	3,802	9,470	121
1981	13,084	2,006	2,257	688	3,896	8,808	103
1982	12,834	1,862	2,279	785	3,218	8,491	88
1983	11,647	1,441	2,254	652	2,929	8,575	58

Finished Steel Products by Uses

1,000 Metric Tons

Containers	Others	For Further Steel Processing (1)	Dealers	Domestic Consumer Total	Export	Total	Year
1,750	377	5,078	21,103	64,351	21,212	85,563	1973
1,609	330	4,725	16,620	55,123	25,088	80,211	1974
1,262	265	3,028	15,208	47,202	22,337	69,539	1975
1,631	344	4,173	14,087	46,603	27,578	74,181	1976
1,706	363	3,792	13,281	44,877	26,771	71,648	1977
1,827	320	3,668	13,974	47,309	24,191	71,500	1978
2,042	331	3,902	15,956	54,496	23,895	78,390	1979
1,841	330	3,914	18,084	55,118	22,024	77,142	1980
1,780	309	3,171	13,712	49,812	21,488	71,300	1981
1,822	295	3,046	13,823	48,550	22,292	70,842	1982
1,826	313	2,828	13,605	46,129	25,154	71,283	1983

Source: Japan Iron and Steel Eederation

Europe

The European steel industry is a diverse mixture of publicly and privately owned companies. In the United Kingdom, France, Italy, and Sweden, the government controls the vast majority of productive capacity. Germany has a number of privately owned steel companies with the government holding a substantial minority interest in several of them.

The European steel industry has gone through a very difficult time. There is substantial overcapacity, and the Commission of the European Economic Community has ordered cutbacks in raw steelmaking capacity. For example, British Steel has reduced capacity from 28 million tons in 1967 to 14 million tons in 1984. Similar, although less dramatic reductions, have taken place in France, Italy, Germany, **Belgium, and the** Netherlands. In Sweden, the government has taken control of the carbon steel industry, leaving alloy and stainless steel production in the private sector. Despite these rationalization moves, there continues to be substantial overcapacity in the European steel industry.

3.1.2 Non-Ferrous

The supply of non-ferrous flat rolled products was examined in much less detail than that for ferrous materials. Because of this, the discussion of non-ferrous materials is necessarily limited.

Canada has a limited number of suppliers of non-ferrous sheet and coil products. The principal suppliers are:

- Aluminum Co. of Canada (Alcan)
- Noranda Metal Industries (Noranda)
- Arrowhead Metals (Arrowhead)
- Reynolds Aluminum Co. of Canada (Reynolds)

Alcan is Canada's major supplier of aluminum sheet and coil. Most grades and sizes are produced, with the exception of aircraft quality sheet. The small size of the domestic aircraft manufacturing market precludes manufacture of this grade. As a consequence, aircraft quality aluminum sheet is imported from the United States or Europe.

Manufacturers reported few problems in obtaining the required grades of sheet and coil aluminum from domestic sources, although the cost of material, especially in comparison to European sources, is a problem. The quality of domestically produced aluminum sheet and coil was reported to be very good. Few problems were reported with regard to aspects such as:

- gauge control and crown
- flatness
- surface finish
- temper
- chemistry control

Copper-based materials are principally supplied by Noranda and Arrowhead. Noranda has the widest product range and is able to offer material in sizes up to 600 mm wide and gauges to 10 mm.

A considerable portion of non-ferrous sheet and coil stock is handled through precision strip mills and metals distributors. These sources are able to provide additional services at reasonable cost and can supply in smaller quantities than the primary producers.

United States capacity for non-ferrous sheet and coil is more than adequate to meet domestic demand. The volume and quality requirements of the packaging, aerospace, and electronics industries in the United States ensure that U.S. aluminum and copper alloy sheet and coil producers will be able to meet market demand. The quality of U.S. non-ferrous sheet and coil stock was reported as very high by respondents to this study. Very few concerns were expressed with regard to chemistry control, gauge and flatness control, temper or surface defects.

Insufficient information was obtained during the field research to allow for analysis of non-ferrous sheet supply in Japan and Europe. In general though, the Japanese and European metalforming industries are well supplied with a wide range of grades and sizes of aluminum, copper, brass, and other non-ferrous flat rolled products.

3.2 Quality of Ferrous Materials

Sheet steel quality has a significant impact on the overall productivity of the metalforming industry. Variations in the physical and metallurgical properties of sheet steel can result in production of bad parts, damage to tooling and press equipment, or delays in production while adjustments are made. In addition, variations in the performance of sheet materials result in the carrying of extra inventory, and the expense of resolving disputes between steel supplier and customer.

Because of the diversity of end-use markets, sheet metal quality means different things to different industries. For example, stamping operations which predominately conduct complex deep draw operations are mainly concerned with variations in gauge and tensile and yield strength. Companies which predominantly form flat products such as stators for electric motors are concerned with crown, camber, hardness, and grain orientation. Surface appearance is a major quality concern of major appliance manufacturers and stainless steel sink manufacturers.

There are significant differences between the overall quality of steel available from Canadian mills and that available from mills in the United States, Japan, and Europe. Respondents to this study provided the following ranking of steel quality:

Japan ↑ highest
Canada/Europe
United States

This ranking is based on the level of mill returns and claims experienced by the metalforming industry. While the survey cannot claim to be comprehensive, it is believed to accurately reflect the experience of the industry in each country. The results of the study are summarized in Exhibit 3.3.

On a region-by-region basis, the following comments can be made with respect to flat-rolled steel quality.

EXHIBIT 3.3

QUALITY OF FLAT ROLLED STEEL

(Percent of Purchased Weight)

COUNTRY	RETURNED TO MILL	MILL ALLOWANCE	RETURNED TO DISTRIBUTOR
Canada	1%	3%	3%
United States	2%	4%	3%
Japan	<< 0.5%	neg	-
Europe	1.5%	2-3%	3%

Source: Based on company interviews

3.2.1 Canada

The quality of Canadian produced carbon steel sheet and coil is generally rated higher than that produced in the United States and Europe for similar grades. Metalforming companies reported rejection rates of approximately 1% of total purchase weight for mill direct purchases. The rejection rate for material purchased from steel distributors averaged approximately 3%, based on answers provided by respondents. It should be noted that these rejection rates refer to material which was not usable and was replaced by the supplier. Material which was only partially defective accounted for a significantly higher proportion of total purchases, in most cases approximately 3% to 4% of mill purchases. These figures are considerably above those experienced in Japan, where much less than 1% of material in total is not usable.

The principal quality concerns of the Canadian metalforming industry are:

- control of gauge variation
- control of camber
- laminations and inclusions
- variations in hardness and tensile yield strength
- surface appearance.

Gauge control and control of yield strength were the most commonly mentioned concerns. Canadian mills generally use SAE and/or ASTM specifications. These specifications allow for considerable variation in gauge. For example, the standard variation for 3.0 mm hot rolled steel is ± 0.18 mm. This variation causes problems in die design. Forming dies are designed to accommodate a particular mean gauge, with allowance for some variation. Problems occur when the variation in gauge is in excess of that expected. HSLA steels were most often mentioned as having significant gauge variation.

Variations in yield strength, hardness and tensile strength, especially for HSLA steels were also of concern. The lack of continuous annealing facilities for HSLA means batch annealing must be used. Significant variations in yield strength within a coil can result from use of batch annealing. Variations in yield strength of more than 20 or 30 ksi (137.9 MPa to 206.8 MPa) for individual coils of the heat were encountered. Tool designers cannot accommodate such significant variations and expect to make quality parts.

Laminations and inclusions are also of significant concern to the metalforming industry in Canada. These defects can cause significant disruptions to the production process. Canadian mills, because they lack extensive capacity for ladle metallurgy and continuous casting of slabs, may be at a disadvantage to mills in other countries in this regard. For example, inclusions and laminations are very rarely encountered in Japanese sheet steels, whereas inclusions and laminations account for approximately 30% of the defects found in Canadian sheet steels.

The quality of alloy and stainless sheet and coil was stated to not be a major concern of the metalforming industry.

The major Canadian steel mills are making significant investments to improve the quality of their products. The recently announced capital investment plans of Dofasco and Stelco are aimed at improvements in steel quality rather than crude steel capacity. The investments include items such as installation of continuous casters, improved sensors for both steel making and rolling, installation of continuous annealing and improvements to cold rolling mills.

3.2.2 United States

The quality of U.S. steel has substantially improved in recent years as a result of mill upgrading on the part of the integrated producers. The upgrading of U.S. steel capability to be more competitive on price and quality is reflected in the following data:

- continuous casting will account for approximately 50% of steel production by 1986 versus 21% in 1981;

- production capacity for high strength, low alloy sheet steels has expanded by over 100% since 1975;

- continuous annealing capacity of approximately 1 million tons has recently been installed by Bethlehem Steel and Inland Steel;

- Republic Steel has installed a sophisticated flatness control system to improve quality.

These improvements are necessary if U.S. mills are to retain their existing market share. Significant quality control problems exist with U.S.-made carbon sheet steels, especially with regard to the following:

- variations in yield and tensile strength
- chemistry control and presence of inclusions
- laminations
- variations in gauge and camber
- other surface defects such as coil breaks and fluting.

These defects result in approximately 2% of material being rejected by fabricators, with a larger percentage (approximately 4%) being subject to mill allowance.

3.2.3 Japan

The Japanese steel industry is acknowledged to be the world leader in steel quality. The Japanese industry has devoted considerable resources to process improvement at all stages of the steel-making and rolling cycle. Indications of the quality of Japanese steel are noted in the tables below:

Data on BOF Operation

	FY1978	FY1980	FY1982	FY1983 (Provisional)
Yield of steel/ingots (%)	92	92	92	91
Vacuum degassed steel (%)	14	24	42	48
Killed steel (%)	53	61	76	85
CC ratio (%)	40	56	79	87
Output of steel/ingots per hour (t/h)	250	280	290	310

Note: Ratios to output of good steel/ingots

Data on Electric Furnace Operation

		FY1978	FY1980	FY1982	FY1983 (Provisional)
Yield of steel/ingots (%)		90	90	90	90
Ratio of vacuum degassing/ ladle refining (%)	Ordinary steel	5	13	13	14
	Special steel	65	71	79	96
CC ratio (%)		53	61	68	77
Specific power consumption (kWh/t)		496	474	452	448
Output of steel/ingots per hour (t/h)		22	25	29	31

Note: Ratio to output of good steel/ingots

Control over chemistry, mechanical properties and gauge of sheet and coil products is excellent in Japan. The Japanese system of Kanban or Just-in-Time deliveries does not permit defects in the steel which could hold up production at metalforming plants. A survey of major metalforming companies in Japan revealed that incoming inspection of material is very limited and that rejection rates for material are well below 1% of total volume purchased. An example of the quality levels achieved in Japanese steel mills is provided by Nisshin Steel Co. Nisshin specializes in flat rolled products. The company has recently commissioned a new hot strip mill at its Kure Works. The new rolling mill is highly automated, and is capable of rolling steels to the following tolerances on a commercial basis:

Gauge Range	Variation (μ, microns)
1.4 - 1.9 mm	-18, +8
2.0 - 2.4 mm	-25, +15
2.5 - 3.1 mm	-18, +8
3.2 - 3.9 mm	-12, +6
4.0 - 4.9 mm	-16, +10

all of the variation is held within 1 standard deviation (1σ), with the mean variation being $\pm 3\mu$. The gauge control is reported to be two times that of the older mill. Crown is reported to be controlled to $^{+10}_{-0}\mu$. All of these tolerances are significantly tighter than those achieved by mills in Canada, the United States, or Europe.

3.2.4 Europe

The quality of European carbon steel sheet and coil is regarded as good. During the course of this project few comments were made as to quality problems. In general, quality concerns were similar to those of manufacturers in North America, especially with regard to variability of yield strength in HSLA and gauge control. Overall, the rejection rate for carbon steel sheet and coil was slightly higher than that experienced in Canada, and stood at approximately 1.5% by weight. There are, however, differences in the experience of the metalforming industry by country. For example, the rejection rate and mill allowance rates in the United Kingdom are significantly above those in Germany. The rejection rate for carbon steels in the U.K. was approximately 3%, but only 1% in Germany. Mill allowances in the U.K. were reported to be approximately 3%, but only 1% in Germany. Respondents in France reported figures of approximately 1.5% for both mill rejections and mill allowances.

3.3 Forging Stock Supply

The principal raw materials required by the industry are ferrous and non-ferrous forging stock, and die blocks. Forging stock is usually obtained in the form of bar or billet stock for impression die forging and cold forming. Bar stock may be used either as lengths of round, round corner square, or square stock; or in the form of coil stock. Billet stock comes either as square or round corner square material. Hexagon shaped bars are also available. Large open die forgings are usually formed from ingot material. Die blocks are generally formed from specially cast and forged ingot.

There is a wide range of ferrous material used for forging purposes. The most commonly forged steels are in the AISI grade ranges of 1020 to 1080. There is a distinct trend to use of steels with special properties, such as boron treated grades for extra hardenability; or resulfurized grades for enhanced machinability. In Japan and Europe, especially, there is also a movement to the use of microalloyed steels, which do not require elaborate heat treatment to achieve the equivalent strength, toughness, and fatigue strength of the complex alloy steels used in North America.

Continuous cast steels for forging use are now receiving considerable interest from forging companies. Continuous cast billets provide greater uniformity in chemical and physical properties than to conventionally cast ingot materials. They are also cheaper to make. Ladle refining practices and the addition of calcium to prevent the formation of large inclusions are also important elements in increasing the popularity of continuous cast steels. In most applications, continuous cast steels must be subjected to a 4:1 or 5:1 reduction to ensure the internal integrity of the steel. This requirement for a preforging operation has had an inhibiting effect on the rate of growth of continuous cast steels for forging use in both North America and Europe.

Aluminum is the most significant of the non-ferrous forging materials, aside from the copper-based metals. Aluminum forgings are used extensively in the aircraft industry, and are finding increased acceptance in other applicaions such as the motor vehicle industry. Significant advances in understanding the metallurgy of aluminum alloys and in the development of light weight Al-Li alloys in the 7090 and 7095 series have been made in recent years. These have resulted in extending the range of application of aluminum forgings. Also significant in contributing to the increased use of aluminum for forging has been the development of precision forging technology. This technology permits the forging of parts with 0 to 1 degree draft angles, and can often eliminate the need for subsequent machining.

The use of superalloys such as Inconel 901, Waspaloy, René 95, Nimonic 115, etc., is restricted to high temperature, severe service applications such as jet engine turbine blades and compressor discs. Forging of these alloys is a highly specialized industry and is restricted to a limited number of companies in the United States, Europe, and Japan.

Other non-ferrous metals include copper, brass, bronze, zinc, magnesium, and titanium. Copper and copper based alloys such as brass and bronze re-forged into such products as valves, taps, etc., for the plumbing industry and for other uses such as hose couplings. These materials are easy to forge and offer excellent machining properties. Zinc alloys can also be forged. These alloys are a Canadian development. The forgings are used in a variety of applications in the transportation, hardware, military, and handling equipment markets. However, the overall volume of zinc forgings is quite small.

Titanium alloys are forged to produce parts for use in high temperature applications, and where strength with light weight is desired. Typical applications are turbine disc for engines, airframe structure components, nuclear power plants and chemical processing plants. Titanium alloy forgings require careful control of chemistry, forging temperature, die lubrications, and forging operation to achieve the desired physical and mechanical properties. Because the process variables are complex, titanium forgings are produced by only a few specialized companies in North America, Europe, and Japan. Current research efforts centre on the development of higher strength, lightweight alloys in the Ti-V-Al-Li-Cu series for aircraft.

The forging industry uses a variety of materials for die blocks. The most commonly used die material is a Ni-Cr-Mo alloy commonly known as #5 die steel. In Canada this material is known as Atlas Steels' "XLO" and Crucible Steels' "Crude". Other commonly used die steels are M2, H13, and some maraging steels. These steels are generally made in electric furnaces. On occasion, they could be made by the ESR method.

The use of carbided, nitrided or other forms of surface treated dies is becoming more widespread. Of special interest now is the use of chemical vapour disposition (CVD) or physical vapour deposition (PVD) techniques for improving the wear resistance of trim dies. The use of cast dies for hot forging in mechanical presses is also of increasing interest to the forging industry.

3.3.1 Canada

The supply of ferrous forging stock for impression die forging is met by a variety of mills in Canada. The principal sources of supply are:

- Stelco - mainly carbon and low alloy grades
- Atlas Steels - alloy and stainless steels
- Burlington Steel - carbon and low alloy
- Lake Ontario Steel (Lasco) - carbon and low alloy
- Algoma Steel - carbon and low alloy
- Ivaco - carbon wire rod
- Manitoba Rolling Mills - carbon and low alloy
- Sidbec-Dosco - carbon and low alloy
- Stelco, Edmonton Works - carbon and low alloy
- Stelco, McMaster Works - carbon and low alloy
- Western Canada Steel - carbon and low alloy

All of these mills, except for Stelco in Hamilton, have continuous casting facilities. Most of the mills have electric furnaces and concentrate on the production of merchant grades of reinforcing steel and light structural shapes. Production of carbon and low alloy bar products suitable for use in forging is limited, except for:

- Stelco, Hilton Works
- Lasco
- Burlington Steel
- Atlas Steels
- Sidbec-Dosco

Atlas Steel is the only mill in Canada with vacuum degassing facilities for production of impression die forging stock.

The supply of forging stock was reported to be adequate, although comments were received with respect to:

- long lead times for delivery
- lack of multiple sources of supply for various grades and sizes of bar and coil stock
- excessive minimum order quantities
- lack of suitable domestic sources of resulfurized and boron treated grades

The supply of high alloy and stainless ingot for use in open die forging is limited. The three major sources of supply are:

- Atlas Steels
- Crucible Steel Canada (Crucan)
- Stelco

Atlas is by far the major supplier. Crucible is mainly a supplier of tool steels, while Stelco's product range is limited to a narrow range of high alloy grades and sizes. Crucible is the only supplier of vacuum induction melting (VIM), vacuum arc remelting (VAR), and electro-slag refining (ESR) grade steels in Canada. Much of this production is consumed internally. Atlas is the only supplier of bottom poured ingot, and its size range is limited.

Some specialized forging companies such as Canadian Steel Wheel in Montreal, which produces railway car wheels, also make their own steel.

The supply of cold forming grades of steel, especially in the alloy grades, is very limited in Canada. Atlas Steels has been producing some of these grades only since 1983, and has limited experience with the metallurgical, physical and chemical requirements of the cold forging industry. Wire rod for the production of fasteners is more readily available. The principal sources of supply are:

- Stelco
- Ivaco
- Lasco
- Burlington Steel
- Sidbec-Dosco

However, for particular grades and sizes, supply can be limited to only one of two sources.

Overall, the principal findings with respect to supply of ferrous forging stock are:

- Canadian mills are limited in the range of grades, sizes, and thermal treatments they produce. This is especially true for open die and cold forming material, and for the higher alloys. This often means there is only one supplier of a particular grade and size in Canada.

- Delivery times and minimum order quantities are considered to be excessive.

The non-ferrous forging industry in Canada is very small. Its needs are readily met by domestic sources for most grades and sizes of copper alloy bar products. Aircraft quality aluminum forging alloys must be imported from the United States, as must aircraft quality superalloys and titanium for the manufacture of turbine blades.

The two principal sources of copper based forging alloys are Noranda Metal Industries and Arrowhead Metals. Noranda can supply both virgin and recycled material, while Arrowhead is mainly a supplier of recycled material. The most significant problems related to domestic supply of copper based forging materials were reported to be:

- seam (cracks)
- chemistry control of alloys
- dimensional variations

These problems are comparable to those reported by copper alloy forgers in other countries.

3.3.2 United States

Forging quality steel billets, bars, wire rod, and ingot are produced by a wide variety of integrated and non-integrated mills. The major integrated producers of forging steels are:

- Bethlehem Steel
- United States Steel
- Inland Steel
- Republic Steel
- Armco Steel
- Roblin Steel
- Carpenter Technology
- Chapparal Steel
- MacDonald Steel
- Raritan Steel

These companies tend to operate very modern electric furnace plants equipped with sophisticated ladle refining, continuous casting and billet conditioning systems, as well as facilities for specialized melting practices.

The supply of forging stock was reported to be adequate. No concerns were expressed by respondents to this study regarding the availability of ferrous forging stock in terms of grade, size or product form.

Supply of copper alloy forging stock in the United States is met by both merchant producers and integrated forging companies. One of the largest copper alloy forging companies - Meuller Brass - is also a major producer of copper, brass, and bronze forgings. No problems were reported regarding the availability of forging stock. Quality concerns were comparable to those in Canada.

Aluminum forging alloys are supplied by Alcoa, Kaiser, and Reynolds. All these companies also operate aluminum forging plants and are very active in the development of new alloys, especially for aerospace applications.

Superalloy and titanium forging stock is produced to very exacting melt practices by companies such as Huntington Alloys, Special Metals Corporation, Carpenter Technology, and the forging companies themselves. Major integrated producers of superalloy and titanium forgings include Cameron Iron, Wyman-Gordon, Pratt and Whitney, and Ladish Co.

Specifications for superalloys and titanium are very exacting, and tend to be customized by producer. As a consequence, it is not possible to comment as to the general level of quality of these materials.

3.3.3 Japan

The Japanese impression die and open die forging industry is well supplied with ferrous forging stock. The Japanese steel industry is very modern and efficient, and can produce carbon, alloy, and stainless steels to very tight specifications using a variety of melting practices. Almost all Japanese carbon forging quality steels are continuously cast from steel produced in Q-BOP, BOF, or electric furnaces. Most of the material has also been subjected to ladle refining and degassing. As mentioned in Chapter 2, most of the open die forging operators in Japan are parts of integrated steel mills and produce their own steels.

Information on the supply and quality of non-ferrous forging stock in Japan was not available.

3.3.4 Europe

The European forging industry is well supplied with forging quality steels. The carbon grades are predominantly produced by state-owned companies, while the alloy and stainless grades are produced by a range of state-owned and private mills. Many of the larger forging companies in Europe such as Bofors (Sweden), Krupp and Thyssen (Germany), and GKN (United Kingdom) have their own steel making plants.

There is a distinct trend in Europe to the use of microalloyed steels. These steels can be air cooled after forging, and do not require the often elaborate heat treatment procedures that high alloy steels require in order to achieve comparable physical and mechanical properties. The more widespread use of microalloyed steels in Europe (and in Japan) than in North America is attributable to a different philosophy regarding metal deformation and mechanical properties. In Europe the basic practice is to take the yield strength of the material as the limiting factor, and to achieve the desired microstructure, physical and mechanical properties by adding alloying elements such as Cb, V, M., etc. In North America, the philosophy has been to start with the ultimate tensile strength of the material, and to achieve the desired microstructure,physical,and mechanical properties by means of heat treatment.

Copper alloy forging stock is produced by a wide range of companies in Europe. Respondents to this study indicated they had experienced no problems with regard to either supply or quality of raw materials. Aluminum forging stock is supplied by Granges Aluminum, British Aluminum, Pechiny, Alusuisse, Voest Alpine, and other primary producers. Supply and quality were reported to be excellent.

Superalloys and titanium are supplied by such companies as Huntington Alloys and Special Metals Corporation of the United States, Henry Wiggin Ltd. of the United Kingdom, and Aubert et Duval Co. of France. West Germany does not have a significant presence in the production of superalloys.

3.4 Quality of Ferrous Forging Stock

3.4.1 Canada

The quality of Canadian ferrous forging stock is generally considered to be good, and better than that available from most foreign sources, in terms of the more common grades and sizes. The Canadian forging industry attempts to use commercial tolerance material as much as possible. Commercial grade tolerances on bars, coils, and billets are generally adequate for hammer forging, but not for use in forging presses and upsetters. Problems with out-of-round, out-of-straight, and out-of-square were reported to account for approximately 20% of in-process defects.

Physical defects such as seams and piping are a major concern of the industry. Seams are reported to be a major problem, accounting for over 50% of in-process defects. Seams are also the chief cause of rejection of raw material, accounting for approximately 75% of rejected material. Surprisingly, seams were reported to be a significant problem even when material was purchased to cold heading and cold forming specificaions. In some cases, forging companies were forced to purchase peeled stock in order to ensure proper quality.

Metallurgical concerns regarding quality related to matters such as:

- soundness of continuous cast billets;
- presence of inclusions;
- grain structure.

There was some concern expressed about the use of continuously cast billet material which had not been subjected to prior reduction. No steel mill in Canada has a GFM or autoforge machine to preforge billet stock. Forging companies were generally of the belief that reduction of continuous cast billets by hot rolling provided insufficient reduction for material which was to be forged into critical parts such as axles.

Inclusions were a major concern to most all forging companies. Inclusions accounted for approximately 50% of rejected forgings. The use of ladle refining techniques such as calcium injection, vacuum degassing, and electromagnetic stirring is very limited in Canada. These techniques have proven to be of significant benefit in controlling inclusions and in promoting uniform grain structure, especially when combined with continuous casting and forge rolling. These techniques have been applied with considerable market and technical success by such companies as Roblin Steel of North Tonawanda, N.Y. No Canadian mill is known to be applying a similar range of technology involving:

- vacuum induction melting
- vacuum degassing
- ladle refining
- shrouding
- continuous casting
- forge rolling
- statistical process control

to produce steels for the cold heading and forging markets.

Overall, Canadian forging companies reported that they rejected an average of approximately 2% (by weight) of purchased steel. The causes of rejection were, in order of importance, as follows:

- out-of-round, out-of-square, out-of-straight
- seams
- other surface defects
- improper chemistry/wrong order
- piping
- inclusions.

Inclusions, however, were the chief cause of rejection of finished forgings. Rejections of finished forgings for other reasons were mainly attributable to process defects.

3.4.2 United States

The quality of ferrous materials for forging use was generally regarded as good. This was especially the case for alloy and stainless steels, which are produced to more exacting standards than are low carbon steels. Carbon steel quality concerns related to such matters as:

- dimensional tolerances
- presence of inclusions
- seams and piping
- variations in chemistry
- variations in metallurgical and mechanical properties

Seams and inclusions were by far the most common quality problem, followed by dimensional variation.

Some mills are instituting statistical process control (SPC) programs to improve quality. These programs are likely to have a significant impact on the manufacturing processes employed by the steel mills. The implementation of SPC will require not only the installation of automated NDT equipment to check for surface and internal defects such as seams, piping, and inclusions; but also equipment to measure dimensional tolerances and to monitor melt chemistry and casting procedures. The overall effect should be a significant upgrading in the technological capability of the steel industry. Similar benefits can be expected to accrue to Canadian steel mills which implement an SPC program.

3.4.3 Japan

The quality of Japanese forging stock is excellent. Respondents to this study indicated almost no material was rejected due to defects such as seams or inclusions or dimensional variation. In part, this is due to the steel making practices employed and in part due to the inspection procedures undertaken by the steel mills. For example, Nippon Steel employs the following inspection procedures for the manufacture of steel bar:

- shot blasting of blooms
- ultrasonic flaw detection after billet rolling
- magnaflux flaw detection following ultrasonic inspection
- billet grinding using centreless grinders
- reinspection by magnaflux, followed by reconditioning
- cold flaw detection after bar rolling, hot shearing, controlled cooling and cold shearing
- final AC and DC magnaflux inspection or automatic flaw detection by Rotomat

These quality control and inspection procedures are much more extensive than those generally employed in North American steel mills and enable independent forge shops to utilize material without inspection.

3.4.4 Europe

The quality of European steels is generally considered to be good. The major quality concerns relate to the presence of surface defects such as seams and excess scale. Piping does not appear to be a serious problem. Based on the results of the field work, the relative order of steel quality in Europe is as follows:

- Germany
- Belgium - for open die forgings, Belgian steel is considered superior
- Sweden/France/U.K.

Reject rates for raw materials are approximately 2.5%, based on tonnage. The principal causes for rejecting material were:

- seams and piping
- out-of-tolerance on size
- improper chemistry.

IV - SHEET METALFORMING TECHNOLOGY

This chapter of the report discusses various aspects of the technologies employed in the sheet metalforming industry. The range of technologies discussed covers the following elements:

- tool design and manufacture
- materials handling
- metalforming
- assembly
- inspection.

4.1 Tool Design and Manufacture

Tool design for sheet metalforming has traditionally been somewhat of a "black art". The success of a stamping company or tool and die manufacturer was highly dependent on the skill of its die designers to develop low cost, efficient tooling. This skill was developed over time and relied in large part on the lessons of trial and error. This experience based system of tool design is changing in response to new demands such as:

- a lack of personnel willing to enter into a period of prolonged apprenticeship to learn the art of tool design;

- the advent of new materials, which prevents the artisan from utilizing his prior experience in the design of tools;

- demands for increased productivity and reduced lead time for tool design;

- demands for increased reliability of parts, requiring a much greater understanding of the behaviour of materials under deformation;

. demands for reduced lead times and increased cost effectiveness of parts, necessitating a greater understanding of the metalforming process and increased speed of the production process.

These changes are resulting in an increased awareness and demand for computer-aided engineering techniques such as computer-aided design and drafting (CADD) and computer-aided manufacturing.

The significance of computer-aided engineering (CAE) techniques is that they allow for:

a) a much greater understanding of the variables affecting the process;

b) greatly increased capability to explore tool design options at reasonable cost;

c) reduced tool manufacture costs through automation of drafting and tool manufacture operations;

d) greatly improved control over the quality of the tooling and of the finished part;

e) integration of the manufacturing process from initial product design to final fabrication.

These factors and their interrelationships are illustrated in Exhibit 4.1.

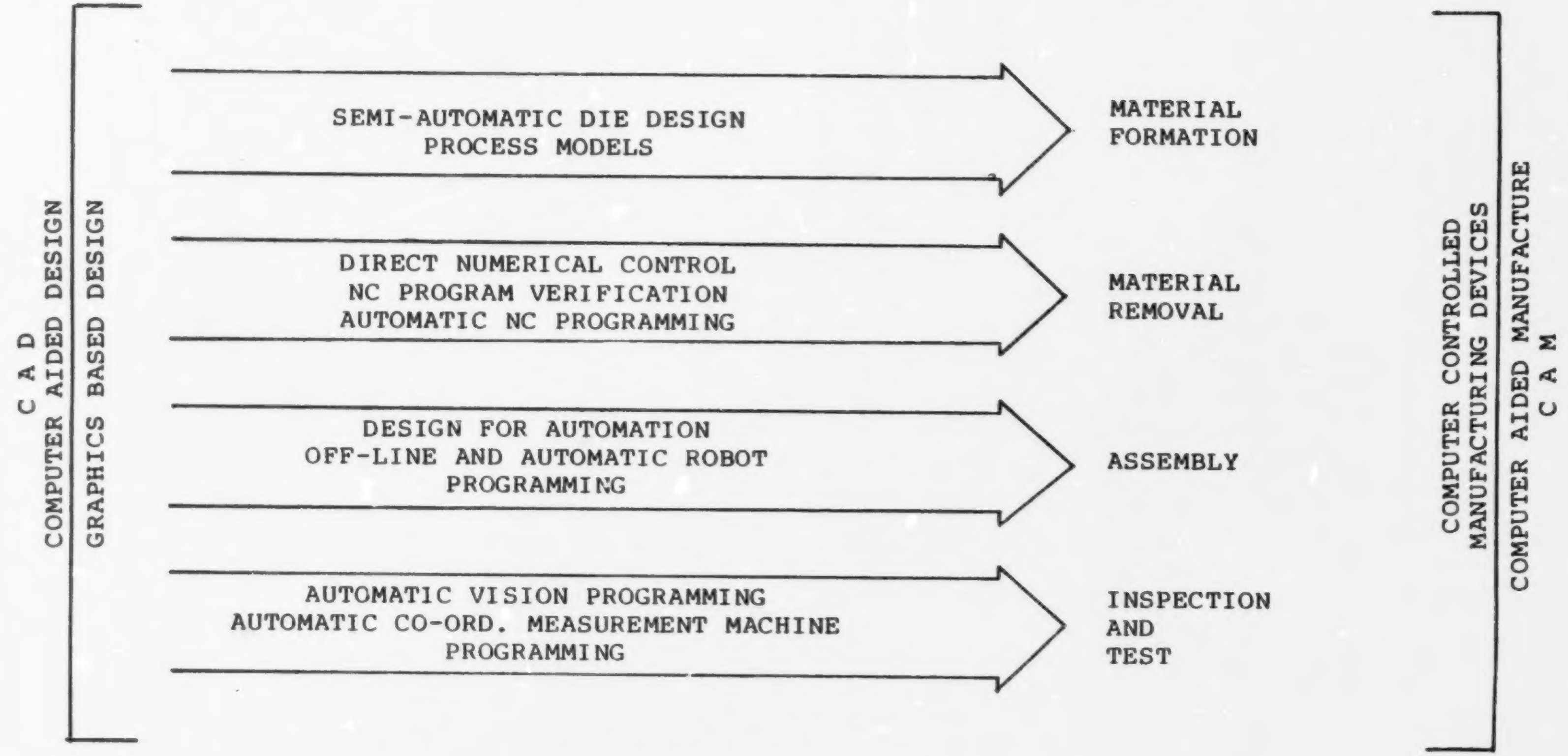
Computer-aided design is the first element of an integrated CAE system. CAD encompasses more than the mere computerization of the drafting table, although this is its most commonly used component. The most comprehensive CAD systems also provide for:

EXHIBIT 4.1

COMPUTER AIDED ENGINEERING

RELATIONSHIP OF CAD/CAM AND DESIGN

DESIGN DRIVEN MANUFACTURING



Source: After J. Richardson
Engineering Digest
May, 1984

- functional analysis
- stress and strain (finite element) analysis
- heat and material balances
- simulation and modelling, including model analysis
- data reduction and analysis
- cost estimating
- NC tool path generation.

CAD systems were first used in the aerospace and automotive industries for evaluation of external envelope shapes. These systems were simple two-dimensional wire frame models and provided little more than the capability to design and draw a multitude of shapes in a short time period. Current CAD systems have greatly expanded capabilities based on three-dimentional models, either solid or wire frame. Solid models offer greater analytical capabilities than do wire frame models, and appear to be the system of choice for engineering design.

Solid modelling systems provide the part designer with a greatly expanded range of analytical features. Not only do they enable the designer to visualize configurations, they can also provide the following capabilities;

- cutaway views
- kinematic analysis
- mass, centre of gravity and other physical dimension calculations
- checks for clearances and interference fits
- unambiguous object definition to establish whether a point ties inside, outside, or on the surface, thus enhancing NC tool path programing.

Solid models are also much more usetul for the creation of finite element models than are wire frame models.

The development of finite element programs that can be handled on a 32-bit minicomputer has opened up significant opportunities for the part supplier to participate in the design process and to improve his tooling design. Most finite element software packages now have automatic mesh generation capabilities, and the results of the analysis can be displayed as contour plots rather than in digital form. These features greatly simplify the data entry and analytical process and bring the technique within the reach of medium-sized companies. This capability will be increasingly necessary as the automotive assemblers begin to place more of the design responsibility for parts on their suppliers.

Finite element analysis will allow the part manufacturer to look at tool design alternatives in order to optimize the forming process. For example, by subjecting various design alternatives to finite element analysis, a part manufacturer can examine the distribution of stresses and strains within the part at various stages of the forming process. Changes in tool design to reduce press power requirements or the number of forming stages can be readily examined, and without the cost of building tools. Considerable savings in time and cost can be expected.

One of the major difficulties encountered in analyzing the sheet metalforming process is its dynamic nature. The deformation process is not consistent within a die set, and thus it is difficult to apply standard values to the stresses and strains being experienced by the sheet. Various methods have been proposed to overcome this difficulty. One method is to take "pictures" of the finite element model at various stages of the forming process. This can be a very costly exercise, involving a large number of calculations. An alternative, and much cheaper method, relies on the use of forming limit diagrams (FLD) as its starting point. The method developed at McMaster University has been shown to have considerable promise.

The ultimate goal in the analysis of tool design is to have a dynamic finite element analysis system which can be used on an interactive basis. This system will require a much better understanding of the behaviour of various alloys under a variety of forming conditions. Also required will be detailed understanding of the interaction of the metal with the lubrication system and the operation of the press. As yet, there is insufficient knowledge of the forming behaviour of the most commonly used metal/lubricant/press systems to make dynamic finite element models practical.

Computer-aided manufacture is the next step to the automated factory. Numerically controlled machine tools were the first elements of CAM. These systems have now progressed to the point where the NC instructions can be produced directly from the geometric model developed on the CAD system, transmitted to the machine tool, and the dies manufactured. Adaptive controls on the machine tool can conduct automatic inspection of the finished die to ensure the NC instructions have been correctly followed.

4.1.1 CAD/CAM in Canada

CAD/CAM use in the Canadian sheet metalforming industry is very limited. The industry is primarily one of "build to print" and thus does not perceive a significant advantage in computerizing its tool design and manufacturing operations. The most complete information on CAD system installations in Canada is shown in Exhibit 4.2. These data indicate that the majority of systems are installed at educational institutions and government centres, and very few in the sheet metal industry. It should be noted that not all of the systems listed are true CAD/CAM systems which have a 3-D design capability. Of the sheet metal systems listed, only one would be considered suitable for design for deep drawn parts and the associated dies.

The use of the government operated CAD CAM centres is limited. During the course of the **research**,only four companies (out of 60) stated they had experience with the Ontario CAD/CAM Centre or the Canadian Institute of Metalworking (CIM). The reasons for not using the centres, or other sources of CAD/CAM information and expertise varied, but included the following:

EXHIBIT 4.2

CAD/CAM SYSTEMS IN CANADA
1983

APPLICATION/INSTALLED IN	NUMBER
Aerospace	4
Machine Shops	26
Educational Centres	20
Provincial Technology Centres	16
Federal government laboratories	5
Plastic mould makers/machine builders	9
Shipyards	4
Sheet metal fabricators	8
Electronics design	4
Consulting engineers	5
Metal extrusion die design	3
Die casting mould design	2
Plate fabrication shops	9
Total	111

Source: Canadian Machinery and Metalworking
March, 1984

EXHIBIT 4.3

SELECTED NC/CNC TOOLS IN CANADA
1983

	NUMBER
Electric discharge machines, all types	92
Press Brakes	32
Automatic Back Gauges	6
Turret Punch Presses	137
Flame and Plasma Cutters/Punch Presses	52
Stretch Forming Machine	2
Coordinate Measurement Machines	12
Total Number of NC/CNC Tools in Canada	3,098
NC/CNC Tools as percent of all Metalworking/Forming Tools in Canada	1.5%

Source: Canadian Machinery and Metalworking
March, 1984

EXHIBIT 4.4

NC/CNC TOOLS IN THE UNITED STATES

Metalcutting Tools	Total	NC/CNC	%NC/CNC
All metalcutting	1,702,833	92,712	5.4%
Plasma and flame cutter/ punching machines	6,336	1,034	16.34%
Metalforming Machines	489,921	9,296	1.9%
Punching and shearing	72,586	6,223	8.6%
Bending and forming (does not include presses)	79,870	2,585	3.2%
All other metalforming machines	337,465	488	0.1%
Coordinate Measurement Machines	6,649		

Source: American Machinist, Nov. 1983
13th Machine Tool Industry

- . CAD is not important to the continuing success of the business;
- . No one in the company knows enough about CAD to be able to evaluate the effectiveness of the assistance;
- . The centres are too expensive;
- . The centres do not respond quickly enough to requests for information;
- . The company did not know the centres were in existence.

This last response was surprisingly common, and indicates much more publicity is required.

Of the companies that had utilized the centres, all had used them as educational sources to learn more about CAD/CAM selection and application, rather than as a source of design help. In all cases, the companies regarded the seminars as useful introductions to CAD/CAM, but with insufficient information available regarding shop floor applications and problems. The major complaint was that practical tool and die design experience and metal fabrication experience was lacking. Based on a review of the 1984/1985 programs and plans of the Ontario CAD/CAM Centre, it is felt that these concerns are being well addressed.

There are several significant trends in the sheet metalforming industry which are likely to lead to an increase in CAD installations in Canada.

- . the major automotive manufacturers have established [illegible] as the target for complete conversion to computerized design and drafting systems. The companies have stated that component suppliers must be capable of accepting computerized design data rather than the blueprints if they are to retain the business;

- the automotive manufacturers are placing an increased responsibility for part design on their principal suppliers;

- the cost of CAD/CAM systems is falling rapidly and the range of appropriate software is expanding.

In terms of particular components of the sheet metalforming industry in Canada, we can note the following:

Automotive

- Design work by the automotive manufacturers is done in the United States. The Canadian subsidiaries have access to the systems in their parent companies;

- Only one major component supplier has a CAD system in place. Other major component suppliers utilize systems in their parent company and/or will be installing systems in the next year (1985).

- There is a definite trend to the use of 3-D solid model systems, in place of 2-D wire frame models.

Aerospace

- Both airframe manufacturers have CAD/CAM systems installed. These systems are used only for st[illegible] [illegible] and analysis.

Agricultural Machinery

- There is very little use of CAD/CAM systems. Some companies are investigating CAD systems for flat pattern development and will be installing systems in 1985.

Miscellaneous Metal Fabrication

- Only three companies were identified which had installed CAD/CAM systems. These systems were for design of progressive die tooling and nesting patterns for sheet metal work.

Electrical Products

- The primary applications are in the development of nesting patterns for use in CNC turret punch machines. Few systems are installed.

Roll Forming Industry

- Use of CAD is restricted to roll design consultants. No Canadian roll forming company is known to have a CAD system for roll design.

4.1.1.2 Computer Numerical Control (CNC) Machining

CNC machining is essential if many of the benefits of CADD are to be achieved. It is only when the design and manufacture of the part are integrated that many of the productivity and quality advantages inherent in CAD/CAM become apparent. In Canada, though, CNC machines are relatively rare. This is especially true in the sheet metalforming industry. Exhibit 4.3 provides some data on the CNC machine tool inventory in Canada. As can be seen, the population of machines suitable for sheet metal work is limited. It should be noted that many of the EDM machines are only employed in the manufacture of dies for the plastics industry and the casting industry.

The use of EDM for the manufacture of metalforming dies is very limited. Most metalforming tools are produced using milling machines. These could be CNC type, tracing or copy type, or standard machines.

Tool manufacture for sheet metal work is done approximately 60% in-house and 40% by independent tool and die shops. The larger companies tend to make their own tools, while the smaller shops are more dependent on outside toolmakers. Roll forming tools are manufactured almost exclusively by outside suppliers. The use of carbided or nitrided dies is very rare. These tools are only used for very long run progressive die operations where close tolerances must be maintained, such as in motor lamination manufacture.

4.1.2 United States

4.1.2.1 CAD/CAM

CAD/CAM use in the United States is well developed in the automotive and aerospace industries. The automotive companies have been very active in installing CADD systems and expect to be able to eliminate all manual design and drafting operations by 1987 or 1988. The use of CADD systems in small companies is very limited. During the course of this study, no company with fewer than 500 employees was identified as having a CADD system, or having access to a system through time sharing.

The major difficulties cited by respondents with regard to CADD systems were:

- high cost for equipment
- training costs
- no in-house die design
- lack of information on appropriate hardware and software.

These responses parallel those of Canadian stamping companies. It is generally felt that until system costs can be reduced to the $50,000 to $100,000 range for stand-alone microcomputer based products, very few companies will invest in CADD.

On an industry-by-industry basis, we note the following with regard to CAD/CAM use in the United States:

Automotive

- The automotive industry is the driving force in the use of CAD/CAM. The three major manufacturers have stated that manual design and drafting will be eliminated by 1988;
- Major component suppliers will be required to have a CAD/CAM capability by 1987/88 to remain as vendors;
- Component suppliers are likely to experience a requirement for increased part design capability, requiring the use of CAD/CAM;
- 3-D solid modeling techniques and finite element analysis packages are becoming standard in the industry;
- Smaller component suppliers are more likely to use CAD/CAM on a service bureau basis, rather than by their own systems;
- Use of CAD/CAM by smaller companies (less than 100 employees) is almost non-existent at present;
- Communications between CAD/CAM systems is a major concern. The IGES protocol would appear to be the system of choice.

Aerospace

- CAD/CAM use is very extensive within the major airframe builders. Substantial reduction in design time and cost have been reported.
- The U.S. Air Force ICAM project is expected to have a significant impact on the industry, especially in terms of the system as it will be applied for flat sheet metal parts.
- CAD/CAM will have its greatest impact in the aerospace industry with machined parts.

Appliances

- The current use of CAD/CAM on the appliances industry is limited. It is currently restricted to mechanical design of components such as compressors.

Agricultural and Construction Equipment

- CAD/CAM use for flat pattern development is becoming widespread in the large companies.

- Smaller manufacturers are unlikely to make extensive use of CAD/CAM even on a service bureau basis.

General Industry

- Use of CAD/CAM systems for nesting design and integration with turret/laser punch presses is likely to become reasonably widespread.

[illegible] NC/CNC Machine Tools

The use of NC/CNC tools is also very restricted in the U.S. metalforming industry. The 1983 census of NC tools by American Machinist indicates that only 1.9% of all the metalforming machines in the United States are NC/CNC. Exhibit 4.4 provides additional data on the use of NC/CNC in the United States. The data indicate that the United States metalforming industry, similar to the Canadian industry, has installed NC/CNC equipment mainly for two-dimensional work by turret punch presses and press brakes.

4.1.3 Japan

4.1.3.1 CAD/CAM

CADD use in the Japanese metalforming industry is not well developed. The automotive companies have by far the greatest number of systems in place, but these tend to be relatively simple 2-D wire frame systems used for envelope design. Only recently have systems been installed in the automotive companies which are suitable for structural design purposes and can generate NC tool path instructions for die manufacture. Outside of the automotive industry, CADD is generally confined to the development of nesting patterns for flat sheet work. This has been most developed in the electrical products industry. Of 28 sheet metalforming companies visited, only 5 had a CADD system. All of these companies were large manufacturers of automotive or electrical products.

Die manufacture in Japan is done predominantly by EDM and CNC machines. Relatively few sheet metalforming companies rely on standard machine tools for die manufacture. Of the companies surveyed for this study, only one did not manufacture its dies by CNC equipment.

The use of CAD/CAM as an integrated system for the design and manufacture of sheet metalforming dies in Japan is restricted to the largest companies. There are descriptions in the literature of systems in use in Nissan and other major Japanese companies. Such systems are beyond the financial capability of most Japanese companies.

[illegible].1.4 Europe

Europe exhibits the most significant differences between countries, industries, and companies in the rate of application of CADD for mechanical design and analysis. The most advanced countries are Germany and Sweden, with Sweden probably having a more diverse range of CADD users. The use of CADD in France is well developed, at least in the automotive and aerospace industries. CADD use in the United Kingdom is restricted to the largest companies in the automotive and aerospace industries, and to the roll forming industry.

The leaders in CADD use in Europe are:

- Mercedes-Benz
- Peugeot-Citroen
- Renault
- Aerospatiale
- British Leyland
- BMW
- Volvo
- Saab-Scania
- British Aerospace
- MBB

Most European CADD systems have been based on 2-D wire frame models and have been drafting oriented. There is now a trend to 3-D wire frame and solid models which incorporate pre and post processors for FEM and tool path generation.

Computer-aided manufacture of sheet metalforming dies is not well developed in Europe except in the automotive and aerospace industries. In general, the component suppliers to these industries are not as advanced in the use of CNC equipment as are the manufacturers, although there are exceptions, especially in Germany and Sweden. Die manufacture in France and the United Kingdom tends to be done mainly by standard methods such as the use of copy or tracing mills.

The roll forming industry in Europe has been quick to adopt the use of CADD/CAM. This is especially true in the case of the United Kingdom.

4.2 Materials Handling

Materials handling in the sheet metalforming industry relates to raw material, work-in-process, and finished goods handling. Of special interest is the use of robots and other types of automated equipment for the handling of work-in-process.

Efficient materials handling procedures can have a signficant impact on the cost of manufacture by reducing the waiting time between processes. In a typical North American or European stamping plant waiting represents over 90% of the time a piece of metal is in the plant. Thus, a reduction in waiting time can result in substantial savings in inventory for raw materials, work-in-process, and finished goods.

Efficient materials handling can also substantially reduce the requirements for floor space. Substantial reductions in capital and operating costs can be achieved by improving the flow of materials in a plant, and thereby reducing the space devoted to moving and storing materials. Improved materials handling procedures can also result in substantial reductions in manpower used to move both raw materials and work-in-process.

Contrasts between North American, European and Japanese practices are described in the following sections.

4.2.1 Canada/United States

Materials handling in Canada and United States stamping plants is very similar, and therefore will be discussed as a single item. The basic features of materials handling in North America are:

a) the reliance on fork lift trucks and tote bins to move and hold materials;

b) the orientation to large batch production.

North American stamping plants, especially those oriented to production of automotive parts, are generally organized to provide a linear flow of material. The layout is strongly affected by the form in which raw material is received and the manner in which it is processed. In most large stamping plants in North America, blanking operations are separate from the forming operations. This means blanks must be loaded into storage bins and then these bins moved to a storage area until needed. The bins are then retrieved, moved to the required press, and the blanks manually fed into the press. Alternatives to this process, such as integrated blanking and forming lines, or the use of destackers, are rarely employed, except in large automotive and appliance stamping plants.

Scrap generated during the blanking and forming process is generally collected in bins located beside or under the press. These bins must be moved by fork lift. Relatively few plants employ sub-floor scrap choppers and conveyors, although their use is widespread in the larger plants.

Movement of material between forming operations can be accomplished in a number of ways. These include:

- manual load/unload
- "iron hand" type units
- pneumatic or magnetic devices
- robots
- progressive die or transfer die equipped presses

Manual and iron hand systems are the most widely employed, especially in the production of larger parts. By far the most common procedure is manual loading and unloading, either to the next press in the line, or to a tote bin. Iron hands can only be used when the presses are directly in line. In most cases, this degree of automation is only possible in large automotive stamping plants which have long run sizes. Manual systems are generally regarded as more flexible and faster when the average run size decreases to approximately 2,000 pieces, or lower. However, the labour requirement is quite high, especially in comparison to methods employed by the Japanese.

Pneumatic or magnetic press feeds tend to be used mainly on small OBI and straight side presses. Automation of the load/unload function can substantially improve productivity by permitting one operator to monitor several presses. However, the press has limitations in terms of the size and complexity of the part that can be handled. This tends to limit the application to small parts for the electrical industry and similar operations.

The use of robots or other types of automation systems for press loading and unloading is not common. Data for 1982 show the following for Canada and the United States:

	% of Total Robot Applications	
	Materials Handling	Machine Load/Unload
Canada	16% (44 units)	6% (16 units)
United States	21% (1,323 units)	17% (1,071 units)

Source: Robotics Institute of America 1982 Survey.

Given that these data refer to all industries, it is apparent that materials handling applications for robots in the metalforming industry are limited. This is confirmed by 1983 data, which show only 2% of all metalmilling and metalforming plants in the United States had work handling robots. The total number of robots was reported as 1,986. Of these, only 468 workhandling robots were reported in use in the fabricated metal products industry; 336 in the non-electrical machinery industry; 266 in the electrical and electronics machinery industry; and 176 in the transportation equipment industries. Robot utilization offers two key advantages to the metalforming industry. These are:

- higher long term productivity than human operators
- consistency of operation in terms of quality and of output.

The use of progressive and transfer die machines is becoming more widespread. Progressive die machines are utilized quite widely in the manufacture of small components for the electrical and electronics industry, and for other industries. Their use greatly simplifies the materials handling function. Transfer die technology is not as widespread. There are very few transfer presses in Canada, and relatively few in the United States, outside of the automotive body stamping industry. The advantages of transfer presses are significant, and will be discussed in more detail in a subsequent section.

4.2.2 Japan

Materials handling in the sheet metalforming industry in Japan is much more automated than in North America. More use is made of stackers, destackers, conveyors and robots to handle both blanks and work-in-process. One of the most visible items in Japan is the limited use of fork lifts in stamping plants. Heavy materials and equipment tend to be moved by overhead crane. Unmanned guided vehicles (UGVs) are also much in evidence in Japan for transfer of work in process, especially in the automotive industry.

The general work flow in Japanese stamping plants is similar to that in North America, with the following exceptions:

- Very little raw material inventory is held. Most materials are received weekly, or even more often. In one instance, a stamping plant received material in the morning at 7 a.m. and shipped finished product at 3:30 p.m. Raw material inventory was essentially zero.

- Blanking lines are closely integrated to the press forming lines. Blanks are generally loaded into blankholders by simple pneumatic or magnetic lifters or by gravity feed. When the blankholder is full it is transferred to the appropriate press by conveyor.

- Forming operations are generally conducted by grouping presses into work cells, thereby enabling all operations to be conducted in a small area and reducing the requirement for materials handling.

- The use of conveyors is much more widespread in Japan than in North America. When combined with a denser spacing of presses, the Japanese achieve significant reductions in the need for materials handling personnel and in floor space.

The use of robots and manipulators for materials handling in the sheet metalforming industry is very evident in Japan. The tendency, however, is to use simple fixed motion lifting and transfer devices, rather than programmable robots. This choice of technology requires much more control over the press operations in terms of placement of the blanks and integration of the operations of the press and the manipulator. In some instances the materials handling devices are married to the tooling, rather than being attached to the press, or being separate.

Fixed sequence robots accounted for 83% of robot applications in press working in Japan in 1980. Most of these were involved in press loading/-unloading functions and transfer of parts between machines. Exhibit 4.5 illustrates the use of robotics in the Japanese stamping and pressing industry as of 1982.

Not all Japanese stamping companies are as automated and efficient as would be indicated only by considering the foregoing. The majority of plants, especially the smaller companies, follow procedures and practices almost identical to those found in North America. There is considerable use of manual loading and unloading of presses. Raw materials and work-in-process are moved by fork lift trucks and transferred in tote bins. The overall view of the materials management function in Japan is thus one of a very modern and efficient sector comprised of the large and medium sized companies; together with a sector utilizing more traditional, North American-style techniques, comprised mainly of smaller companies. The production efficiencies achieved by the larger companies are significant, and account for a large proportion of the cost advantage enjoyed by the Japanese stamping industry over its North American counterparts.

4.2.3 Europe

Materials handling technology and practices in Europe are very similar to those employed in North America. Transfer of raw materials and work-in-process tends to be handled by fork lift truck and tote bins. Automation of part transfer between press operations is limited. On a country-by-country basis we can note the following:

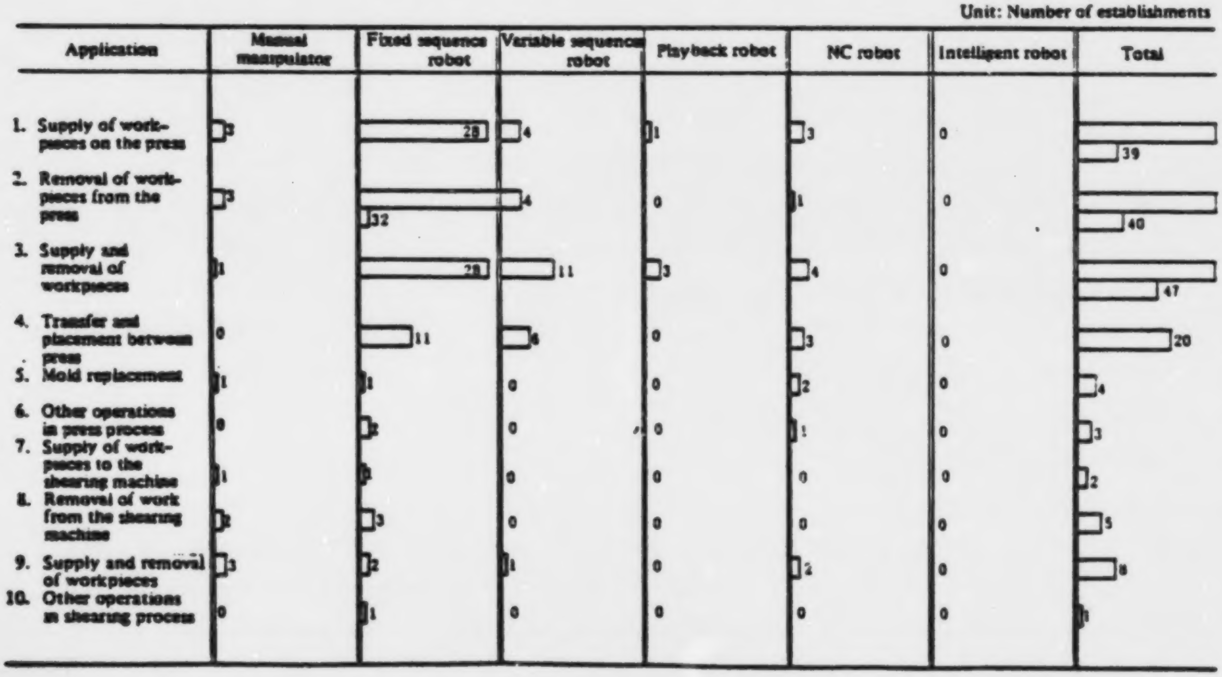
EXHIBIT 4.5

STATUS OF ROBOT OPERATIONS IN METAL PRESS AND SHEARING PROCESS
(232 Establishments)

Type of Robot	Number of robotized establishments	Installation rate (%)	Number of robots installed	Average number of robots per establishment (Note)
a. Manual Manipulator	10	4.3	33	0.14
b. Fixed Sequence Robot	66	28.4	614	2.64
c. Variable Sequence Robot	16	6.9	68	0.29
d. Playback Robot	4	1.7	8	0.03
e. NC robot	9	3.9	19	0.08
f. Intelligent Robot	0	–	0	–
Total	85	36.6	742	3.20

Note: These figures include non-robotized establishments.

APPLICATION OF ROBOTS IN METAL PRESS AND SHEARING PROCESS



Source: Robotics Industry of Japan, 1982.
Survey Nomura Research Inc.

Sweden

- Automated materials handling systems in the metalforming industry are well developed in Sweden, especially in the automotive industry.

- Sweden has the second largest robot population in Europe (1,450 in 1982), and has made effective use of AGVs for transferring blanks and moving partially assembled components to work stations.

- Approximately 50% of the robots installed in Sweden were used for material handling and machine load/unload functions.

Germany

- Materials handling functions for transfer of raw materials and work-in-process is automated to a high degree in the automotive and appliance industries.

- Robot use in Germany is the highest in western Europe, with 4,300 installations at the end of 1982. Materials handling and machine load/unload represented 18% of applications in 1982.

- There is a trend to the use of transfer press technology for the manufacture of deep drawn parts and the use of fully automated CNC turret punch systems for flat metal work. Both of these technologies significantly reduce the requirement for materials handling.

France

- Materials handling in France is very similar to North America, with extensive use of fork lifts, tote bins, and manual handling of work-in-process.

- The automotive industry is much more automated than the rest of French industry, in terms of materials handling.

- 1982 robot installations numbered 9,993, including 9,000 variable sequenced manipulators. Forty-five percent of the total were employed in material handling and machine load/unload functions.

United Kingdom

- The range of technology employed is extremely wide, with the automotive industry being the most automated.
- Use of conveyors and manipulators for transferring material is very limited outside of automotive industry.
- Robot use in the United Kingdom is limited. The latest survey recorded 803 robots in use in 1983, of which 31% were used for materials handling and press load/unload functions.

4.3 Forming Technology

Forming technology in the stamping and pressing industry consists of consideration of the following:

- blanking
- forming and piercing, including drawing
- trim
- assembly

These operations involve:

- cutting of a blank of suitable size and shape from a coil or large sheet;
- forming and piercing (if required) of the blank to the desired shape;
- trimming of the format part to the final part dimensions;
- assembly and inspection of finished parts;

The basic differences in the technologies employed for metalforming in each region of interest are described in the following section.

4.3.1 Canada/United States

The stamping and pressing industries of Canada and the United States employ very similar technologies. This is not surprising in view of the high degree of integration of industries in the two countries. The machines used in the Canadian metalforming industry are mainly of U.S. manufacture or design, and the products manufactured are very similar in design.

The principal differences in forming technology between Canada and the United States relate to scale factors, and to differences in industrial structure. Thus, where product line and size of company are similar, the equipment employed in Canadian and U.S. plants is similar. Where product lines are similar, but plant sizes are different, there are differences in the forming technology employed.

The relative age of machinery is a good indicator of technological capability in the metalforming industry. Older machinery is generally less reliable, less accurate and slower than more modern machinery. Thus, one would expect the quality and productivity of an industry to decline as machinery ages. In the case of Canada and the United States, the available data indicate the following

		Age of Metalforming Tools		
Country	Survey Year	0-9	10-19	20 +
Canada	1978	23%	51%	26%
United States	1983	18%	45%	37%

Source: American Machinist, 13th Inventory, Nov. 1983.

These data would tend to indicate that Canadian and United States metalforming technology is roughly comparable, and this is generally the case.

A comparison of Canadian and United States metalforming machinery technology is detailed in the following sections.

4.3.1.1 Punching and Shearing Machines

These machines are used mainly in the manufacture of flat sheet metal components, usually in the lighter gauges.

The machines can be equipped with lasers or plasma cutting heads for increased precision and capability. Flame cutting machines do not have punching mechanisms, and are used for cutting complex patterns in plate.

These machines are easily adapted to CNC operation, and there is a strong trend in this direction. The machines are also ideal for adapting to flexible manufacturing systems (FMS) concepts through the use of the automatic storage and retrieval (AS/AR) systems, CADD, CNC, and automatic tool change using a turret system.

Data available on Canadian and U.S. systems show the following:

1983 Canada: 195 CNC back gauges, turret punch presses, shears and thermal cutting machines

1983 United States:

Machine Type	Number of Machines	% Machines by Age (yrs) 0-9	10-19	20 +
NC Thermal Cutting	1,034	83%	8%	9%
Non-NC Thermal Cutting	5,302	60	26	14
NC Punching	5,468	68	26	6
NC Shearing	755	54	26	19
Non-NC Punching, plate & sheet	27,783	31	38	31
Non-NC Shearing, plate & sheet	28,705	32	36	32
Sheet & Plate Processing Systems	1,634	39	24	37

universe = 165,356 plants

Source: American Machinist, Canadian Machinery & Metalworking

These data indicate Canadian companies have not adopted the use of CNC punching and shearing equipment as quickly as the U.S. companies. This does not mean, though, that Canadian companies are not aware of the benefits of CNC equipment, and the FMS. For example, two of the best examples of such systems are to be found in Canada. These are Selox Manufacturing in Toronto, and Mark Hot Ltd., in Montreal.

The FMS at Selox Manufacturing is a self developed system based on the use of AS/AR systems and Weidemann turret punch presses. The system utilizes a VAX 11/780 minicomputer. The benefits of the system have been substantial, with productivity improvements of 10 x for the shearing operation and 19 x for the punching operation being recorded. Set-up time has been virtually eliminated, and scrap substantially reduced. The factory has been designed to operate in an unmanned mode for the night shift.

The system installed at Mark Hot Ltd. of Montreal was also designed in-house. The CNC centre utilizes Weidemann and Witney turret punch presses, a CNC Optishear and robots. The system has resulted in reduction of scrap (offal) from 27% to 3% - 5%.

4.3.1.2 Press Brakes

Press brakes are used to form acute angle bends in sheet metal. They are widely used in the agricultural and construction equipment industries to form bends in sheet and plate work. Press brakes have changed little in design over the years, and machines which are over 80 years old can still be found in everyday use. The most significant advance on press brake technology has been the introduction of CNC controls for both mechanical and hydraulic powered machines. In Canada, there were reported to be only 32 CNC press brakes in operation in 1983. This would represent much less than 1% of the Canadian press brake population. U.S. data indicate CNC press brakes represent approximately 6% of the total number. The distribution by type is illustrated below:

Type	Number	% by Age (Yrs)		
		0-9	10-19	20+
NC bending + forming	2,585	58%	27%	15%
non-NC press brakes mechanical	29,585	22	43	35
non-NC press brakes, hydraulic + pneumatic	10,978	53	35	12

Source: American Machinist

The trend to hydraulic and pneumatic machines is noticeable, and attributed to the greater degree of control that can be achieved with these machines.

4.3.1.3 OBI and OBG Presses

These presses are the most ubiquitous in the sheet metalforming industry. They are most often employed in small plants with low production volumes and low profits. As a consequence, many of the presses are quite old. These presses may be manually fed, or fed by automated systems such as robots, pick-and-place units; or press feeds utilizing mechanical, magnetic, or pneumatic devices. Press feeds are normally employed if the press is fitted with progressive dies. It is also possible to equip OBI and OBG presses to handle transfer dies, although this is quite rare. 1983 data on U.S. presses is detailed below. Data for Canadian presses would provide a similar analysis.

Type	Number	% by Age (Yrs)		
		0-9	10-19	20+
OBI and OBG, mechanical	147,530	19%	37%	44%
C-frame and gap, hydraulic	24,328	20%	34%	32%

Source: American Machinist

4.3.1.4 Straight Side Presses

These presses may be of mechanical hydraulic or pneumatic type, and either single, double or triple action. Data available on the U.S. press population indicate the following:

Type	Number	% by Age (Yrs) 0-9	 10-19	 20+
Mechanical, single point	14,345	22%	30%	47%
Mechanical, 2 pt.	14,584	20%	34%	46%
Mechanical, other	22,514	20%	30%	50%
Hydraulic, single action	18,806	37%	35%	29%
Hydraulic, double action	2,212	32%	42%	26%
Hydraulic, other	7,946	39%	32%	29%
Pneumatic, all types	17,656	47%	37%	16%

Source: American Machinist

Data for Canada would tend to show a significantly lower proportion of hydraulic presses and a press population of somewhat older vintage for all types of presses.

The data for the United States indicate a trend to hydraulic presses. These presses are favoured despite slower speeds, due to their lower purchase, operating and maintenance costs; their ability to develop full power at any point during the stroke; and the ability to control the speed of the stroke. This latter capability is especially important for deep drawing applications, and this is the main application for hydraulic presses.

Double and triple action mechanical and hydraulic presses represent a very small proportion of the press population. In Canada, these presses are employed almost exclusively in the automotive parts industry. They are generally the most modern and well equipped presses in the plant. Features that can be found on these presses, and which are generally not found on other presses include:

- rolling bolsters
- hydraulic clamping systems for dies and bolsters
- electronic monitors to measure strain rates, etc.
- automatic load and unload devices

However, these features are not universally installed, but are to be found only in the best plants. Based on the research for this study, it is estimated that the features identified above would be found in less than 30 plants in Canada.

The low level of utilization of features such as hydraulic clamping systems and rolling bolsters is surprising, in view of the productivity enhancements they offer. Retrofitting of existing presses to accommodate quick die change can be accomplished at a relatively low cost, and yield substantial benefits. The lack of use of quick die change technology is surprising in view of the Canadian marketplace, which is characterized by relatively short runs of individual components. The Japanese industry, in contrast, has recognized the need for flexible production and has adopted production systems to meet the requirement. For example, typical die change times range from about 2 hours to over 6 hours for medium sized (500 to 1,000 ton) presses in Canada and the United States. By equipping presses with quick-die-change capabilities, and standardizing on bolster and bed plate sizes, shut heights, draw down speeds, etc., die change time can be reduced to approximately 5 minutes. The effect on productivity and the ability to do short runs is obvious. An example will illustrate this:

Parameters: 600 ton mechanical press
4 changeovers per month

die set-up times: 6.0 hr, 2.1 hr, 0.10 hr

Results:

	6.0 hr	2.1 hr	0.10 hr
Economic Order Quantity	15,400 units	9,000 units	215 units
Increase in up time	-	187.2 hr/yr	283.2 hr/yr
% increase in capacity			
(3 shift operation)	-	2.28%	3.45%
(2 shift operation)	-	3.48%	5.27%

Obviously, the more set-ups required per month, the greater the benefits of reductions in set-up times in terms of improved production flexibility, increased productivity, increased plant capacity; and perhaps most important, a reduced need to purchase additional presses to accommodate order requirements. It is likely that as Just-in-Time systems become more important for competitive success, that quick-die-change (QDC) procedures will become more widespread.

Transfer presses, especially those used in the manufacture of automotive parts, are rarely used in Canada. Their use is somewhat more common in the United States, due to much greater production of light gauge sheet metal automotive parts. As previously mentioned, North American companies have a preference to utilize a series of presses linked by robots, iron hands or other devices or manpower to move the material to each forming stage. Such procedures are costly in terms of capital and labour. For example, one plant visited in Japan was producing large rear end components for the Honda Prelude at 18 spm (strikes per minute) on an 800 ton transfer press. The labour requirement was 2.5 operators. This system replaced four 800 ton straight side presses and 8 operators which would be typical for a North American plant.

Conversion of standard mechanical or hydraulic presses to handle transfer dies is not widespread in Canada or in the United States. The preference is to utilize presses designed specifically to handle transfer dies. The use of electronic controls and programmable logic controllers (PLCs) to monitor and control press operations, die conditions and parts production is limited. These electronic devices are installed on modern presses, but relatively few presses built prior to 1975 have been retrofitted. Where such devices have been installed, they have been found to improve product quality and increase die life by increasing the consistency of operations. Reductions in scrap rates of 20% and improvements in die life of 10% were reported by respondents.

4.3.1.5 Roll Forming

Roll forming processes are well developed in North America. They account for approximately 40% of all the sheet metal formed in Canada and the United States. Roll forming processes are able to shape sheet metal with very little scrap being generated in the process. Materials related problems are relatively rare in the industry, although variations in yield strength, and thus springback, do cause concern.

CADD/CAM for roll design and manufacture is of major interest in North America and in other countries. Significant reductions in design time and cost, and improvements in part design, can be achieved by use of CAD/CAM. This particularly applies to the forming of pre-painted and vinyl coated materials, where extreme care is required so as not to exceed specified stress/strain parameters and cause damage to the surface of the material, or other defects such as rippling.

In Canada, there are no roll forming companies with an in-house CADD/CAM system for roll design. This capability is provided by outside vendors. No information was obtained regarding the use of CAD/CAM systems by U.S. roll forming companies. However, as approximately 40% of U.S. roll forming companies manufacture their own rolls, in-house systems are believed to be in use.

4.3.2 Japan

The technology employed in the Japanese stamping and pressing industry is not significantly different from that to be found in North America. By and large, the press equipment used in Japan is very similar, and in fact, is often of North American design or manufacture. There are however, significant differences in how the technology is employed. These differences relate to:

- more use of conveyors and transfer devices to reduce the materials handling component;
- emphasis on reduction of die set up times by standardization of die sets, bolster/adapter plates, shut height, use of rolling bolsters, and hydraulic clamping, and mechanical handling equipment;
- organization of presses into work cells to enable automatic transfer of material from press to press;
- more widespread use of transfer presses to reduce the total number of presses required to form a part and the attendant materials handling;

- minimization of inventory and storage space through use of Just-in-Time production techniques;

- emphasis on statistical process control and quality;

- minimum use of lubricants to reduce waste, maintain cleanliness, and reduce cost;

- high equipment utilization (90%-95% available) as a result of effective preventive maintenance programs and quick die change procedures;

- use of more highly trained and motivated employees than is general for North America.

In summary, production technology is not much different from that employed in the best North American plants. The Japanese have been successful because they have adopted proven production technology and production management techniques in a more consistent manner than North American companies.

It must also be added, though, that Japanese companies do tend to utilize much more modern machinery. For example, a survey conducted by the Japanese Ministry of International Trade and Industry in 1981 showed the following:

Age of Metalforming Machinery

0 - 2 yrs	- 18%
0 - 7 yrs	- 41%
8 - 12 yrs	- 28%
13 + yrs	- 32%

This age distribution is significantly younger than that for Canada or the United States, and does have an impact on productivity and product quality.

Another factor that must also be considered is the superior knowledge of metalforming behaviour that the Japanese have. Japanese metal stamping companies employ a much greater number of engineers and technicians for a given production volume than do North American companies. This results in:

- an ability to analyze, design, and build modifications to presses and ancillary equipment using in-house resources;

- a better theoretical understanding of the deformation process, resulting in a better understanding of the origins of deformation problems and mechanisms to overcome these problems.

Other features of Japanese production technology include:

- use of subfloor scrap choppers and conveyors thus reducing the requirement for materials handling;

- more extensive use of electronic controls on equipment to monitor press and die conditions;

- production of smaller sized stampings, especially in the automotive business. This increases the requirements for assembly but also increases the yield from a given area of metal, thus offsetting assembly costs. Yields in the automotive parts industry are typically 75%-80% versus 60%-65% in North America.

The use of a hydroforming, bulgeforming, and other hydraulic based technologies is more common in Japan than in North America. These technologies have been primarily developed in Japan.

Automation of press operations in Japan is mainly by simple devices. The use of programmable robots for press loading/unloading and part transfer is limited. The preference is for fixed travel manipulators using pneumatic or magnetic lifting and transfer devices. Their use requires well ordered production flows and good production management if flexibility is not to be sacrificed.

4.3.3 Europe

European metalforming technology is equal to that of North America. There is, however, a wide disparity in technology between countries and between industries within countries. For example, we note the following with respect to the age of metalforming machinery in Europe:

Survey Year	Country	% Distribution by Age (Yrs) 0-9	10-14	15-19	20+
1980	Germany	4%	18%	1) 48%	
1980	France	35%		2) 33%	32%
1984	United Kingdom	3) 27%		4) 44%	5) 29%

1) 15 + years
2) 10-19 years
3) 0-7 years
4) 8-21 years
5) 22 + years

Source: American Machinist, 13th Inventory, 1983
Metal Working Production, 5th Survey, 1984

The relatively young age of machinery in the United Kingdom is attributed to the significant incentives available to United Kingdom manufacturers for investment in new equipment.

Throughout Europe, the automotive and appliance industries are the most technologically advanced. Sweden and West Germany are the technological leaders in terms of forming techniques and manufacturing methods, followed by France, Italy, and the United Kingdom as approximate equals in the automotive industry.

The aircraft industry in Europe is very well developed in terms of forming technology. The industry shares much of its technology through ventures such as the Airbus consortium. As a consequence the differences in technology are slight. The same equipment and methods are employed in France, Germany, the United Kingdom, and Sweden.

Outside of the automotive, appliance, and aircraft industries, the differences in forming technology become more significant. Sweden and West Germany tend to utilize more modern production tools such as CNC turret punch presses, Hydroform presses and transfer presses than does the industry in France or the United Kingdom. The contrast in the United Kingdom is especially vivid, with an extremely wide variation in technological capability between the automotive stamping industry and the general contract stampings industry.

On a country-by-country basis we can note the following.

4.3.3.1 Sweden

The Swedish sheet metalforming industry is dominated by the production of automobiles, appliances, and engineered products. Swedish industry is dominated by such major companies as Volvo, Saab, Electrolux, SKF, ASEA, and Bofors. These large companies are highly integrated, producing some of their raw materials such as steel and non-ferrous metals, manufacturing components, and assembling the components into finished products. These major companies are also highly diversified in terms of their product lines. The result of this vertical integration and market diversification is a metalworking industry with extensive knowledge of the theory of metalforming behaviour and of practical manufacture.

Within the automotive industry, Volvo and Saab are highly advanced in their use of technology. As noted in a previous chapter, these companies make very extensive use of CAD/CAM for design and analysis of sheet metal parts. They also make extensive use of robots for materials handling, assembly and finishing operations. Both Volvo and Saab are noted for their use of AGVs in their assembly operations. The main technological characteristics of the Swedish sheet metalforming industry are:

- widespread use of modern metalforming machinery, often equipped with CNC or microprocessor controls;
- an emphasis on flexibility in production through use of robotics, quick-die-change procedures and efficient materials handling;
- management and technical personnel with a good understanding of the theoretical aspects of metalforming;

- more widespread use of hydraulic presses than in most other European countries;

- very efficient layout of equipment to promote production efficiencies.

4.3.3.2 West Germany

The West German stamping and pressing industry is highly developed due to the influence of the automotive industry. West Germany is also the home of several of the major machinery manufacturers such as Weingarten, Schuler, Hasenclever, and Trumpf. These companies are very active in the development of new pressworking methods and machinery.

The automotive industry in Germany is the most advanced component of the stamping and pressing industry in terms of its forming technology. The industry makes extensive use of transfer presses and robots, as illustrated in Exhibits 4.6, which show installations at Mercedes-Benz.

Unfortunately, this study took place during the metal workers' strike in Germany. As a consequence, visits to other sheet metalforming plants were not possible. A review of the literature of German sheet metalforming technology, however, indicates the following:

- a strong orientation to increasing flexibility in production through use of CAD/CAM, CNC machines and robotics;

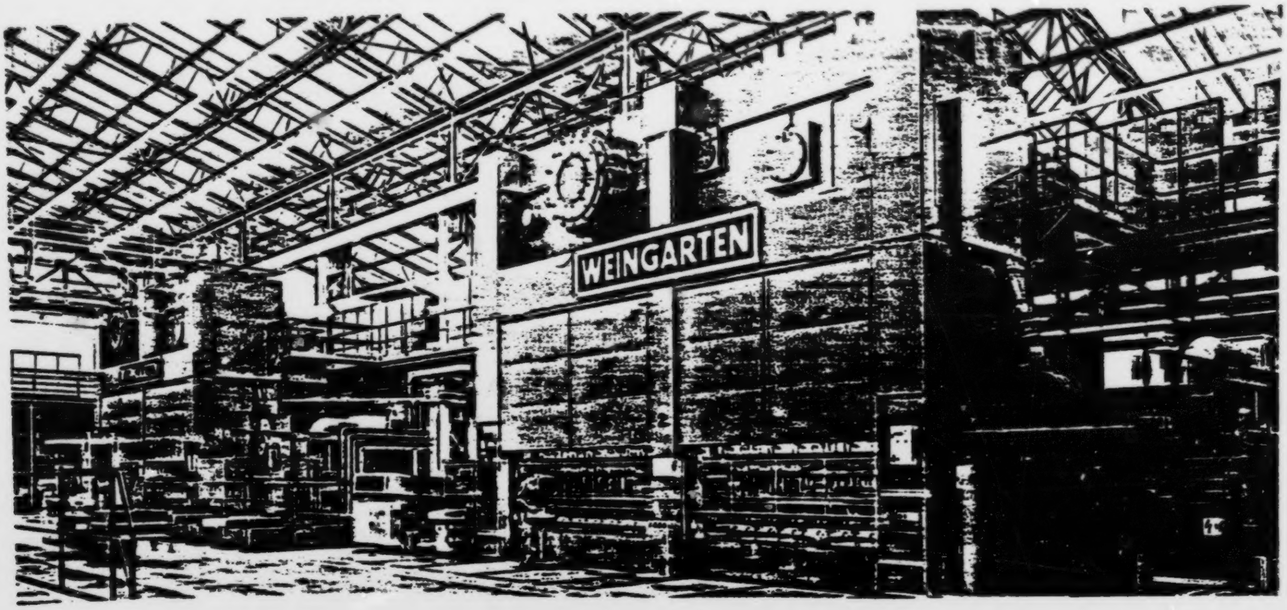
- a superior knowledge of metalforming behaviour, from a theoretical basis, than is general in Canada;

- a trend to the use of hydraulic powered machinery for sheet metalforming;

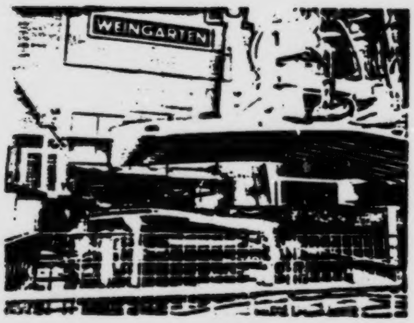
- more effective utilization of university research, with an orientation to applied research rather than basic research of metalforming;

EXHIBIT 4. 6

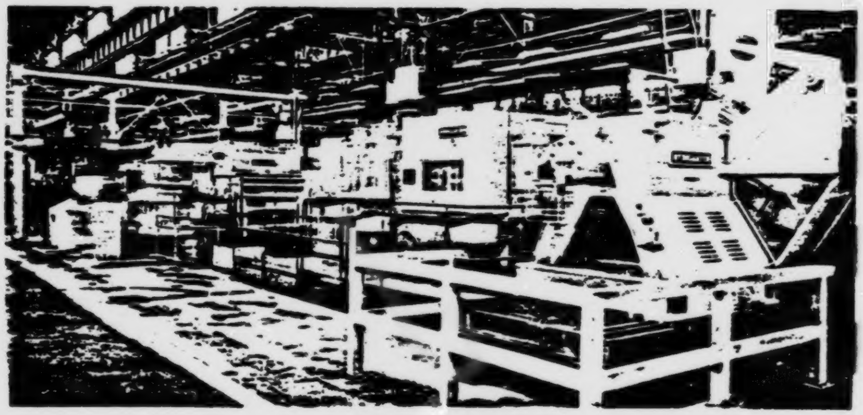
PRESS OPERATIONS AT MERCEDES-BENZ PLANT



AUTOMATIC TRANSFER PRESS LINE FOR BODY PANELS
AT MERCEDES-BENZ PLANT



AUTOMATIC PART REMOVAL
AND STACKING OF
AUTO PARTS



AUTOMATIC COIL PROCESSING LINE
FOR BODY PANEL BLANKS

- a better trained and more knowledgeable work force than is typical for Canadian plants.

4.3.3.3 France

The stamping and pressing industry of France, similar to that in the rest of Europe, is dominated by the automotive industry. Renault, the state-owned manufacturer, operates one of the most sophisticated CAD/CAM systems in Europe and employs modern transfer press technology for the manufacture of sheet metal parts. Peugeot-Citroen has less modern metalforming machinery, and tends to purchase more of its parts supplies from outside vendors than does Renault.

Some of the major characteristics of the French stamping and pressing industry are:

- use of analytical techniques such as determination of n and r values Erichsen test, LDR (Limiting Drawing Ratio) and other mechanical properties to evaluate the formability of materials is widespread;
- equipment utilized in the industry is of standard design. Relatively few machines are equipped with electronic sensors, etc., aside from the automotive industry;
- the use of fixed sequence manipulators is widespread;
- die making is **predominantly** carried out on conventional equipment, rather than CNC equipment;
- the use of transfer presses and other presses equipped with coil feeds is becoming more important;
- unlike Sweden and Germany, mechanical presses are preferred in France.

EXHIBIT 4.7

AGE OF U. K. METALFORMING MACHINERY

AS OF 1983

	Total	Post 1981	3-7	8-12	13-21	22+
N.C. Turret Punch Presses	563	28	367	151	17	---
N.C. Press Brakes	887	53	621	186	18	9
N.C. Coordinate Nibbling	166	20	118	28	---	---
Robots	803	265	466	72	---	---
E. D. M.	3,859	154	1,176	1,080	772	77
Press Brakes, Non N.C.						
Mechanical	4,395	44	923	791	1,187	1,494
Hydraulic	5,775	115	2,368	1,502	1,040	751
Stretch Forming	433	--	121	52	74	178
Vacuum Forming	160	--	29	49	40	42
Hydraulic Presses	22,565	226	5,190	4,739	6,995	5,416
Pneumatic Presses	5,772	58	2,540	1,212	1,212	750
Mechanical Presses	52,024	520	9,885	9,885	13,526	18,208
Punching & Shearing	24,806	496	7,938	5,953	5,209	5,209
Forging	9,095	182	1,637	1,091	1,910	4,275
Total	131,303	2,161	33,379	26,791	32,000	36,409

Source: Metalworking Production
5th Survey of Machine Tool and Production Equipment, 1984

4.3.3.4 United Kingdom

There is an extreme range in the United Kingdom stamping and pressing industry in terms of technological capability. The automotive and aerospace industries are well developed, while some other segments operate with very outmoded equipment. One of the most visible aspects of the industry, aside from the large automotive and aerospace companies, is the dense packing of presses and labour intensive materials handling to be found in most plants. A second and somewhat surprising finding of the study is the relatively young age of metalforming machinery in England. At the same time, there still exists a considerable amount of old machinery. In many cases, the old and new equipment are to be found within the same plant, producing the same parts. A recently completed survey of machinery in the United Kingdom illustrates the factors just noted. The results are listed in Exhibit 4.7. It should be noted that small companies have generally been the most active in purchasing new machinery, whether of NC of conventional design. This trend was also evident in other countries.

On an industry-by-industry basis, we can note the following with respect to the United Kingdom metalforming industry:

Automotive

The automotive industry in the United Kingdom has undergone a period of rapid and massive restructuring to make it more competitive with other European manufacturers, and the Japanese. This restructuring has resulted in the development or introduction of new manufacturing technology. It has also placed severe pressure on components suppliers to upgrade their capability, in order to retain the business. Examples of the impact of technological change in the United Kingdom automotive industry include:

- British Leyland (BL) is the only manufacturer actually designing cars in the United Kingdom. Design work for other manufacturers such as Ford, Vauxhall, Talbot, etc., is conducted outside of the United Kingdom.

- Significant move to the use of HSLA steels and plastics to reduce weight.

- Increased emphasis on flexibility in production and reduced down time for die changes.

Appliance Industry

The appliance industry in the United Kingdom has been extensively modernized in the past few years. New plants have been built which incorporate the latest technology in terms of materials handling, forming, and assembly. Two of the best examples are a Philips plant near Halifax and a GEC plant in Wales. The productivity increase resulting from the use of transfer presses is notable. For example, the GEC plant recorded a productivity increase of 3x on its panel production line, while the Philips plant experienced a productivity increase of 9 x on its line.

Other Industry Segments

The technology used in other industry segments is very disparate. The use of CNC press brakes and turret punch presses has increased significantly in the past few years. At the same time, many companies are operating with very old, hand fed OBI presses in very poorly laid out factories. The result of these differences in equipment is a wide variation in productivity and quality. For example, a stainless steel sink manufacturer reported an in-process reject rate of less than 1% and material utilization of approximately 85% by using Hydroform presses. A manufacturer of stainless steel cookware reported an in-process reject rate of 2.5% and a material utilization rate of 65% by using mechanical presses. Other stamping and pressing companies reported in-process reject rates of up to 5%.

In summary, the key features of metalforming technology in the United Kingdom are:

- extremely wide variation of equipment both within and between industry sectors;

- resulting wide variation in ability to reduce offal, rejects, and improve productivity.

- recognition of the need for flexibility in production.

4.4 Assembly Technology

This section describes the various types of assembly technologies employed in the sheet metalforming industries. Sheet metal components can be fastened by a variety of methods. The most common are:

- Welding
  - electric resistance
    - spot and seam
    - projection, butt, flash, etc.
  - electric arc
  - energy beam processing
    - electron beam welding
    - laser welding
  - gas welding
    - MIG
    - TIG
- Brazing and Soldering
- Mechanical Fastening
  - bolts, rivets, slot and flange, seam rolling, screws, etc.
- Adhesives

Fastening systems can be manual, semi-automatic, or fully automatic using a variety of equipment such as transfer machines, robots or other devices.

4.4.1 Canada/United States

4.4.1.1 Welding and Other Thermal Fastening Systems

Welding is by far the most popular method of assembling sheet metal components manufactured from carbon steel and stainless steel. Spot welding predominates, especially in the automotive assembly business. Spot welding offers a number of advantages over other joining techniques, the chief being:

- adaptable to manual, automatic, or robotic systems
- minimal skilled labour requirement
- speed.

In Canada and the United States spot welding was one of the first applications for robots. It is by far the largest application in Canada, with approximately 45% of all applications in 1982 and an estimated 65% of all applications in 1984. In the United States, spot welding robots represented approximately 35% of all applications in 1982.

Despite the increase in robotic spot welders, most spot welding operations are conducted using either manually operated units or automatic welders with jigs. Automatic welding systems lack flexibility and are generally only used in high volume production of standard parts.

Arc welding finds its principal application in the joining of heavy gauge sheet metal components such as are found in agricultural and construction equipment. Arc welding is also utilized to assemble the structural sheet metal components of automobiles and other products. Systems may be manual, semiautomatic, or fully automatic.

Robots are becoming more common in arc welding applications, although much more research on sensory systems is required before robots can be as effective as either a manual system or a fully automatic system. Robotic arc welding systems account for approximately 10% of all robotics installations in the U.S. In Canada, arc welding is believed to account for approximately 5% of the estimated 800 robot installations in 1984.

Gas welding machines for MIG and TIG welding are not common in Canada. The procedures require a skilled operator. In Canada, production volumes for stainless steel, aluminum and other components requiring MIG or TIG welding are generally too low to permit economic operation of automatic systems. Automatic gas welding systems in the United States are reported to number approximately 5,400 and to be found in approximately 5% of metalworking and metalforming plants.

Energy beam processing systems such as electron beam and laser welding units are very new technology. There is no data available on their use in Canada. In the United States there are a reported 612 electron beam welding units and 325 laser welding units. They are primarily used in precision manufacturing operations within the aircraft, automobile, and electrical and electronics industries.

Brazing and soldering operations can be either manual or automatic. Manual systems are by far the most common in both Canada and the United States. Automatic soldering systems are to be found in applications such as can manufacture. Data for the United States indicate there are approximately 14,200 brazing systems, representing 13% of U.S. metalworking and metalforming plants in 1983.

4.4.1.2 Mechanical Fastening and Assembly

Mechanical fastening and assembly by means of bolts, rivets, screws, etc., remains a popular method of assembly of final products. These processes are still undertaken largely by hand due to difficulties in orienting parts and fasteners for automatic assembly. At the present time, robots are generally not capable of performing this task. However, the development of vision systems utilizing lasers, sonar, or television cameras is expected to have a significant impact on assembly technology.

Robots equipped with sensors for sight and for tactile sensing should be capable of performing very complex assembly operations. By employing such robots manufacturers will be able to present parts to the robot in a disorganized manner, rather than the very structured pattern that is currently required. Tactile sensors incorporating force feedback or torque registers will be able to insert and tighten fasteners to the required tolerances. As yet, robots with these capabilites are still largely in the experimental stage. Data for Canada and the United States for 1982 indicate the following:

	Number of Robots	
	Canada	United States
Vision		
Simple	9	37
Real Time	2	18
Tactile Sensing		
Force Feedback	7	10
Torque	10	10
Other	-	60

Source: 1982 Worldwide Robotics Survey
Robotics Institute of America

The range of application of sensory equipped robots is expanding rapidly, as the cost of the robots declines. For example, it is estimated that approximately one half of the robots sold in the United States in 1987 will have vision capability. Applications such as line tracking and bin picking are predicted to become commonplace. The development of torque and force feedback sensors will enable robots to undertake tasks such as screw driving. When sight and force sensors are combined, the result should be a very useful robot for mechanical assembly. Data available from a recent Delphi survey of robotics indicates that robotic mechanical assembly will account for 12% of annual robot sales of 10,000 units in 1990 and 16%, or 2,560 units in 1995.

The development of sensory robots for mechanical assembly will likely lead to redesign of products to enable robots to function effectively. Designing for assembly, rather than for engineering elegance, can have a significant impact on total manufacturing cost. For example, IBM redesigned a series regulators forrobotic assembly and achieved a reduction of 18% in terms of part types (9 versus 11) and 55% in terms of discrete parts (37 versus 86). The benefits of the redesign were:

- easier, automatic assembly by robot
- improved quality
- reduced manufacturing, production control and inventor costs.

These benefits of designing for ease of manufacture as well as engineering function have been well recognized by the Japanese. Much of the success of the Japanese manufacturers can be attributed to the early recognition of this basic principle.

An interesting example of the application of several of the points just noted is to be found in Ford Motor Company's Climate Control Division plant in Troy, Michigan. This plant produces air conditioner controls for Tempo/Topaz and Escort/Lynx cars in six different models. The assembly line combines manual, automatic, and robotic operations within a single system controlled by a PLC. The system is reported to have a first run capability of 97-98%, versus 80-82% for fully manual assembly.

4.4.2 Japan

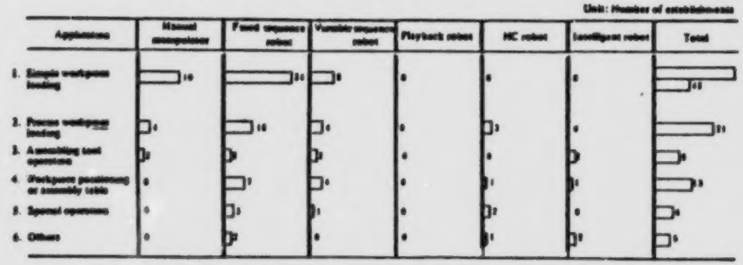
As previously noted, the Japanese stamping and pressing industry undertakes a considerably larger volume of secondary operations than does the industry in North America. Typically, the Japanese stamper concentrates on value-added production of assemblies, rather than simple parts. In Japan, assembly operations such as welding account for over 50% of plant space and represent approximately 75% of the volume of production. These ratios are considerably higher than those to be found in North American plants.

Robotics use in welding and assembly operations in Japan is widespread. Data for 1982 indicate 8,052 robots (25.2% of all robots) were employed in welding operations and 6,099 (19.1%) in assembly operations. The results of another 1982 survey of robotic use in Japan are summarized in Exhibit 4.8. These data indicate spot robots accounted for 7.0% of all robots, and arc welding robots for 2.1% of applications. Assembly robots were reported to represent 24.0% of applications. There was a reported total of 2,934 robots

EXHIBIT 4.8
JAPANESE ROBOTICS USE WELDING - 1982 - FINISHING AND ASSEMBLY APPLICATIONS
(Based on Sample of 802 Companies)

INDUSTRY	APPLICATION						Total Robots Used in Industry Sector
	Spot Welding	Arc Welding	Painting	Plating	Machining	Assembly (Ex Welding)	
General Machinery	8	111	24	-	260	4	486
Electrical Machinery	205	27	44	8	597	562	1,790
Automobile	678	39	20	2	1,542	170	3,136
Transportaion Equipment (non-Auto)	-	5	7	-	24	1	41
Precision Machinery	-	-	3	16	980	2,335	3,591
General Metalworking/ Metalforming	11	63	16	17	257	12	769
Total Robots Used In Industry	921	274	126	132	3,679	3,149	13,120

Application of Robots in Assembly Process



Status of Robot Operations in Assembly Process
(294 Establishments)

Type of Robot	Number of robotized establishments	Installation rate (%)	Number of robots installed	Average number of robots per establishment (Note)
a. Manual Manipulator	15	5.1	79	0.27
b. Fixed Sequence Robot	43	14.6	2,707	9.21
c. Variable Sequence Robot	10	3.4	103	0.35
d. Playback Robot	0	–	0	–
e. NC robot	7	2.4	21	0.07
f. Intelligent Robot	13	4.4	239	0.81
Total	59	20.1	3,149	10.71

Note: These figures include non-robotized establishments.

Sources: 1982 Survey of Industrial
Robots in Japan,
Nomura Research Inc.

with vision and/or tactile sensors in Japan in 1982. As can be seen from Exhibit 4.8, fixed sequence manipulators accounted for 86% of reported robot installations in assembly operations in Japan.

It should be noted that many of the robots used in the Japanese metalforming industry are of the home-built type. Japanese companies have often found it cheaper to design and build robots to their own specific requirements, rather than rely on outside vendors. This trend is in contrast to North America, where metalforming companies tend to rely on vendor expertise for robot selection and installation.

The contrast in robotics applications between Japan and North America also serves to highlight two of the principal differences between the metalforming industries of each region. These are:

- a preference for simple, low cost, easily implemented solutions to manufacturing problems in Japan versus a tendency to seek an elaborate "high-tech" solution in North America;
- a proportionately larger number of production oriented engineers and technicians in Japan than in the United States in Canada.

4.4.3 Europe

European assembly technology is very similar to that of North America. The stamping and pressing industry predominately manufactures parts rather than full assemblies or finished products. As in North America, assembly technology in the stamping industry is oriented to resistance welding and arc welding of parts. Other types of assembly, such as mechanical fasteners, have a much more limited application in the stamping industries of Europe. There were no data available to indicate the level of assembly carried out by the European stamping industry. However, based on observation of a variety of operations in Sweden, West Germany, France, and the United Kingdom, we would estimate the average level of assembly as being approximately 30%. Sweden and Germany would appear to have a higher level of assembly than France or the United Kingdom. It is estimated that Swedish stamping plants conduct assembly operations on

EXHIBIT 4.9

EUROPEAN WELDING AND ASSEMBLY ROBOTS
1982

COUNTRY	WELDING ROBOTS		ASSEMBLY	TOTAL ALL ROBOTS IN USE	SENSORY EQUIPPED ROBOTS					
					VISION		TACTILE			TOTAL
	SPOT	ARC			SIMPLE	REAL TIME	FORCE FEEDBACK	TORQUE	OTHER	
SWEDEN	- - - 260 - - -		15	1,450	50	3	15	10	-	78
WEST GERMANY	- - -1,916- - -		122	4,300	20	-	15	-	30	65
FRANCE	- - - 605 1)- -		3,000 1)	9,993 1)	-	55	- - -	- 3 -	- -	58
UNITED KINGDOM	249	157	32	1,152	5	-	2	10	-	17
T O T A L	- - -3,187- - -		3,169	16,985	75	58	- - -	- 85-	- -	218

1) includes 9,000 variable sequenced manipulators

Source: 1982 Worldwide Robotics Survey
Robotics Institute of America
British Robotics Association

more than 50% of their production, while in the United Kingdom companies undertake assembly operations on only about 20% of their production. These differences can largely be attributed to structural differences in industry makeup. For example, Swedish and German industry tends to have a higher level of vertical integration than does French or British industry.

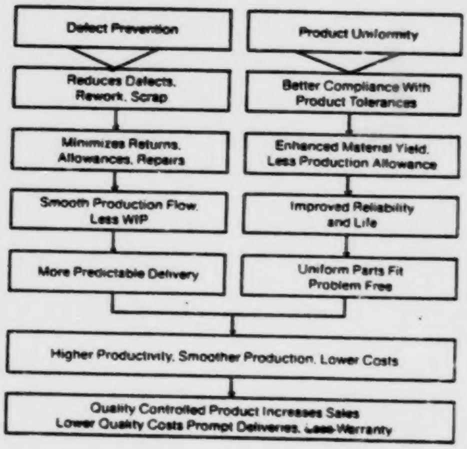
Exhibit 4.9 provides data on the utilization of robots for welding and assembly operations in Europe. The data also provide information on the utilization of robots with vision or tactile sensors. The use of robots for resistance and arc welding operations is by far the most important assembly related application. These robots are principally found in the automotive industry. The use of robots for parts assembly as opposed to fabrication, is much more limited. The data shown in Exhibit 4.9 distorts the importance of assembly robots by including a large number of variable sequenced manipulators, which are used in France, principally in the electronics industry.

Sensor equipped robots are still largely experimental in nature. They are, however, finding practical application in the Swedish automotive industry and in France, especially in the automotive industry (Renault), aerospace and electronics. In the United Kingdom, sensory robots have not yet been accepted by industry. Respondents to this study indicated a preference for robots with laser or sonar vision systems rather than television systems. Television based systems were stated to be an overly complex solution to what are mainly relatively simple part recognition problems.

4.5 Inspection and Quality Control Technology

Inspection and quality control procedures in the metalforming industry are undergoing a period of significant and rapid change. In North America, the driving force has been the automotive industry's recognition that quality can be as effective a competitive tool as are price and style. The cost of quality, as measured by in-process inspection and rework costs, in-process reject rates, customer rejections and warranty costs, has come to be recognized as a very significant element of total costs. Companies are discovering that by improving quality control at all stages of manufacture, that overall costs can be significantly reduced. In addition, companies are discovering that better analysis of the process variables affecting quality can result in substantial improvements to the manufacturing process, yielding lower manufacturing costs. These elements are illustrated below:

THE BENEFITS OF QUALITY


Defect Prevention
Product Uniformity
Reduces Defects, Rework, Scrap
Better Compliance With Product Tolerances
Minimizes Returns, Allowances, Repairs
Enhanced Material Yield, Less Production Allowance
Smooth Production Flow, Less WIP
Improved Reliability and Life
More Predictable Delivery
Uniform Parts Fit Problem Free
Higher Productivity, Smoother Production, Lower Costs
Quality Controlled Product Increases Sales
Lower Quality Costs Prompt Deliveries, Less Warranty

While North American manufacturers have understood these relationships from a conceptual point of view, the general attitude has been that high quality costs more money than can be justified. Recent data comparing the performance of the American and Japanese home air conditioner industries demonstrates the very clear relationship between high quality, high productivity, and low costs.

The study of the air conditioner industry covered 90% of the United States production and 100% of Japanese production of room air conditioners. The results of the study show that, on average, Japanese manufacturers experienced an assembly line defect rate approximately 70% lower than the U.S. manufacturers. After sales rework calls were also significantly lower for the Japanese. The data also showed Japanese productivity was considerably higher, despite a more diverse product range, and that average warranty costs for Japanese manufacturers are at least 3 times lower than the best U.S. company. These data are shown in Exhibit 4.10 and 4.11.

EXHIBIT 4.10

Exhibit I Quality in the room air conditioning industry 1981-1982

	Internal failures				External failures			
	Fabrication: coil leaks per 100 units	Assembly-line defects per 100 units			Service call rate per 100 units under first-year warranty coverage			
		Total	Leaks	Electrical	Total	Compressors	Thermostats	Fan motors
Median								
United States	4.4	63.5	3.1	3.3	10.5†	1.0	1.4	.5
Japan	< .1	.95	.12	.12	.6	.05	.002	.028
Range								
United States	.1-9.0	7-165	1.3-34	.9-34	5.3-26.5	.5-3.4	.4-3.6	.2-2.6
Japan	.03-.4	.15-3.0	.0015-.5	.0015-1.0	.04-2.0	.002-.1	0-.03	.001-.2

*Although most companies reported total failure rates for 1981 or 1982, complete data on component failure rates were often available only for earlier years. For some U.S. companies, 1979 or 1980 figures were employed. Because there was little change in U.S. failure rates during this period, the mixing of data from different years should have little effect.

†Service call rates in the United States normally include calls where no product problems were found ("customer instruction" calls); those in Japan do not. I have adjusted the U.S. median to exclude these calls; without the adjustments, the median U.S. service call rate would be 11.4 per 100 units. Figures for the range should be adjusted similarly, although the necessary data were not available from the U.S. companies with the highest and lowest service call rates.

Exhibit II Quality and productivity

Grouping of companies by quality performance	Units produced per assembly-line direct labor man-hour actual hours*		Units produced per assembly-line direct labor man-hour standard output†	
	Median	Range	Median	Range
Japanese manufacturers	NA‡	NA	1.8	1.4-3.1
Best U.S. plants	1.7	1.7§	1.7	1.4-1.9
Better U.S. plants	.9	.7-1.0	1.1	.8-1.2
Average U.S. plants	1.0	.6-1.2	1.1	1.1-1.7
Poorest U.S. plants	.35	.35§	1.3	.8-1.6

*Direct labor hours have been adjusted to include only those workers involved in assembly (i.e., where inspectors and repairmen were classified as direct labor, they have been excluded from the totals).

†Computed by using the average cycle time to derive a figure for hourly output, and then dividing by the number of assembly-line direct laborers (excluding inspectors and repairmen) to determine output per man-hour.

‡NA = not available.

§In this quality grouping, man-hour data were only available from a single company.

Source: Harvard Business Review, Volume 61, No. 5, 1983
Author: David A. Garvin

EXHIBIT 4.11

Exhibit III Quality and costs

Grouping of companies by quality performance	Warranty costs as a percentage of sales*		Total cost of quality (Japanese companies) and total failure costs (U.S. companies) as a percentage of sales†	
	Median	Range	Median	Range
Japanese manufacturers	.6%	.2-1.0%	1.3%	.7-2.0%
Best U.S. plants	1.8	1.1-2.4	2.8	2.7-2.8
Better U.S. plants	2.4	1.7-3.1	3.4	3.3-3.5
Average U.S. plants	2.2	1.7-4.3	3.9	2.3-5.6
Poorest U.S. plants	5.2%	3.3-7.0%	>5.8%	4.4->7.2%

*Because most Japanese air conditioners are covered by a three-year warranty while most U.S. units are covered by a warranty of five years, these figures somewhat overstate the Japanese advantage. The bias is unlikely to be serious, however, because second- to fifth-year coverage in the United States and second- to third-year coverage in Japan are much less inclusive—and therefore, less expensive—than first-year coverage. For example, at U.S. companies second- to fifth-year warranty costs average less than one-fifth of first-year expenses.

†Total cost of quality is the sum of all quality-related expenditures, including the costs of prevention, inspection, rework, scrap, and warranties. The Japanese figures include expenditures in all of these categories, while the U.S. figures, because of limited data, include only the costs of rework, scrap, and warranties (failure costs). As a result, these figures understate total U.S. quality costs relative to those of the Japanese.

Exhibit IV Quality and product stability

Grouping of companies by quality performance	Median number of design changes per year	Median number of models	Median number of design changes per model*	Median percentage that peak production exceeded low production†
Japanese manufacturers	NA‡	80	NA	170%
Best U.S. plants	43	56	.8	27
Better U.S. plants	150	81	1.9	63
Average U.S. plants	400	126	3.2	50
Poorest U.S. plants	133	41	3.2	100%

*Column 1 divided by column 2.

†The figures in this column were derived by dividing each plant's largest daily output for the year by its smallest (nonzero) output for the year.

‡NA = not available.

Source: Harvard Business Review, Volume 61, No. 5, 1983
Author: David A. Garvin

The reasons for the superior quality and cost performance of the Japanese industry are not entirely consequences of superior raw materials or manufacturing technology, for these are very similar to conditions in North America. The superior performance is also due to management attention to process detail and general management attitudes to costs. In short, the Japanese are better managers by reason of:

- a commitment to quality expressed in daily, careful review of the causes of defects;
- a belief that product quality is management's top manufacturing priority, and a transmittal of this belief to the production line;
- a strong commitment to effective product design from a consumer point-of-view;
- a commitment to constant quality improvement, measured in reduction of defects;
- effective information systems to identify sources of defects at each stage of manufacture and in the field;
- an emphasis on reliability engineering and careful evaluation of new designs before production;
- an emphasis on design for ease of manufacture and reduction of parts numbers;
- an emphasis on worker training to understand the total manufacturing process;

EXHIBIT 4.12

DEMING'S 14 POINTS FOR MANAGEMENT

1. Constancy of purpose for improvement
   - Plan for the long term
   - Put resources into research and education
   - Constantly improve design of product or service
   - Maintain equipment, furniture, fixtures, etc.
2. Adopt the new philosophy
   - Stop taking defects for granted
   - Find out their true costs - defects are expensive
3. Cease dependence on mass inspection
   - Quality comes from improvement of the process, not inspection
   - Routine 100% inspection is the same thing as planning for defects
4. End the practice of awarding business on price alone
   - Price without measure of quality is irrelevant
   - Purchasing managers have a new job
   - Reduce the number of suppliers
5. Constantly and forever improve the system
   - Aim for continual improvement in every activity
   - The lion's share of process improvement comes from management
   - When a process is under control, improvements come from study of the system not defects
6. Institute modern training methods
   - Eliminate variable standards
   - Statistical methods must be learned by hourly employees
7. Institute modern supervisory methods
   - Remove barriers between hourly worker and pride of workmanship
   - Foremen to be empowered and directed to inform management of improvement opportunities
   - Supervision is meant to help people
8. Drive out fear
   - Employees should not be afraid to ask questions
   - What is best for the company should override rules
9. Break down barriers between staff areas
   - R&D, purchasing, sales, etc., must learn about production
   - Don't rush to production until design problems are eliminated
10. Eliminate numerical goals, posters and slogans for the work force
    - Goals without a road map to reach the goals are useless
    - The real goal is never-ending improvement
11. Eliminate work standards and numerical quotas
    - Many quotas take account only of numbers not quality
    - Proper supervision is superior to standards and quotas
12. Remove barriers that hinder the hourly worker
    - Workers want to take pride in their work
    - Barriers can be everywhere - poor training, materials, tools
13. Institute a vigourous program of education and training
    - Productivity and quality improvements means a re-allocation of people
    - Train everybody on statistical techniques (but don't begin massive immediate use of charts by workers)
    - Retraining should keep workers familiar with new materials, methods, designs etc.,
14. Create a management structure that will push every day on the above 13 points
    - Top management must be committed
    - It should secure competent advice
    - Everyone in the company needs a road map for improvement

Source: W. Edwards Deming, Quality, Productivity, and Competitive Position (Massachusetts Institute of Technology, Center for Advanced Engineering Study, Cambridge, Mass., 1982)

- effective use of statistical process control techniques to monitor the production process;
- use of inspection procedures suited to the rapid detection and correction of manufacturing deviations;
- extremely careful selection and monitoring of vendors to eliminate purchased defect.

These practices flow out of the work of Dr. W. Edwards Deming in promoting the concept of statistical process control (SPC). Dr. Deming's basic philosophy rests in the belief that by controlling the manufacturing process, one can achieve substantial improvements in product quality and productivity. To achieve this objective involves much more than charting. Many other factors need to be in place for charting to improve quality and productivity. These are detailed in Exhibit 4.12.

Other advances in inspection and quality control include:

- development of machine vision systems utilizing television cameras, lasers, sonar, and gamma rays to measure surface defects and critical dimensions;
- increased use of coordinate measurement machines for verifying die dimensions and part dimensions;
- increased use of automatic test equipment to verify correct operation of finished assemblies.

4.5.1 Canada/United States

Canada

In Canada, inspection and quality control is still largely a manual process based on traditional methods. By and large, stampings are subjected to cursory visual inspection during removal from the press. Roving inspectors, rather than the press operators, are generally assigned this task. Inspection of finished assemblies generally involves visual and dimensional checking using micrometers, calipers and height gauges. The procedures just described do not identify process related variations, nor do they ensure good product quality. As a consequence, in-process rejects are typically 2% to 3% or more, of production, and customer rejects are typically 4% or more.

The characteristics noted above are representative of small independent stamping companies. Larger companies, especially those supplying the automotive industry, utilize different inspection procedures. Much more formal quality control procedures are required. In larger companies the typical inspection and quality control procedures are:

- dimensional checking of first (proof) part using jigs, fixtures, and gauges;
- checking of parts at press using simple go/no-go fixtures;
- visual inspection of parts at press;
- random sampling of completed parts and assemblies and checking of dimensions using contact gauges, fixtures, and/or optical comparators on a non-statistical basis.

The increased emphasis on quality in the automotive industry is resulting in the introduction of statistical process control procedures in both stamping plants and automotive assembly plants. It is generally assumed that SPC requires the use of sophisticated coordinate measurement machines. This is not always true, and several major auto parts manufacturers in Canada have developed SPC programs utilizing conventional equipment. For example, several companies utilize elaborate measuring jigs to record critical dimensions. The use of jigs, however, has two major drawbacks. These are:

1) Cost
   - Jigs can be very expensive. For example, a measuring jig for an inner door pillar and panel assembly costs approximately $100,000. Separate jigs are required for each part, thus total costs could be very high.

2) Time
   - Measurement of dimensions is very time consuming. For example, measurement time for the inner door panel and pillar assembly is approximately 3 hours. Obviously, the cost of inspection is very high.

The use of automated equipment to reduce inspection costs is limited in Canada. For example, there are only a reported 12 coordinate measurement machines in Canada. Of these, one was in use by an auto part manufacturer, two by farm machinery manufacturers, and the balance were employed in machine shops.

The use of machine vision systems for dimension checking is also limited. Systems are in place at some automotive assembly plants to measure the fit and finish of cars on the assembly line. These systems use lasers. These systems however, are not at present being used to gauge assemblies or parts. There is no known use of machine vision systems for parts measurement in other industries in Canada.

United States

Inspection and quality control procedures in Canada and the United States are very similar. Thus the techniques employed in small Canadian stamping plants are also used in similar sized U.S. plants. Larger U.S. plants, however, do exhibit differences in inspection and quality control from comparable Canadian plants. These differences relate to the extent of use of SPC and advanced technology for inspection.

Statistical process control has had much more widespread use in the United States than in Canada. The results of a recent survey conducted by the American Metal Stamping Association on the rate of use of SPC indicate the following:

- 47% of companies in the metalforming industry use SPC techniques;
- of those with an SPC program, it is used in 10% of the jobs;
- 15% use a statistical analyzer;
- 10% use coordinate measuring machines;
- 19% include charts with part shipments;
- of the companies participating in the survey, 46% of their customers insist on SPC with an additional 6% responding that their customers will in the future;

The benefits of SPC can be substantial. Two examples are detailed below:

- Manufacturer of short run stampings.
    - average lot size 1,500 units
    - average number of customers, 1,000
    - customer reject rate before SPC = 1.5%
    - customer reject rate after SPC = 0.5%
      (12 months SPC experience)
- Pontiac Division, General Motors
    - 65% press utilization before SPC
    - 94% press utilization after SPC

4.5.2 Japan

Inspection and quality control in Japan is taken very seriously. All of the companies interviewed for this study had effective SPC programs in place. These companies ranged from very small firms with 50 employees to extremely large companies with over 30,000 employees. Five of the companies interviewed had won the Deming Prize, which is awarded for excellence in quality. All of the 26 companies interviewed had coordinate measurement machines. The use of machine vision systems was restricted to large manufacturers of automotive parts and electronic assemblies.

4.5.3 Europe

Inspection and quality control technology in Europe is very similar to that employed in North America. In small companies the reliance is still on mass inspection of completed parts. Larger companies have much more sophisticated quality control procedures to meet the requirements of the automotive and aerospace industries. The use of SPC procedures is rapidly increasing in all European countries, principally as a result of demands for increased quality by the automotive industry. For example, British Leyland is now requiring all of its suppliers to conform to the SPC standards established by the British Standards Institute. The result has been a significant reduction in rejections by British Leyland, from approximately 6% of stamping purchases to 1.[illegible].

V - FORGING TECHNOLOGY

5.1 INTRODUCTION

Forging technology covers an extremely wide range of topics ranging from die design to inspection of finished forgings. This chapter of the report discusses the technologies available to the forging industry and the extent of their application in Canada, the United States, Japan, and Europe. Particular attention is paid to items such as:

- use of CADD for die design
- use of CAM techniques for die manufacture
- stock heating practices
- forging processes
- heat treatment processes
- inspection processes, especially as they relate to the use of NDT equipment

This chapter is not designed as a comprehensive review of the full range of developments in forging technology. Rather, it is designed to highlight the general level of technology within each country of interest, and to indicate important new developments. The chapter covers hot and cold forging, including cold heading.

5.2 Die Design, CAD/CAM and Die Manufacture

The forging industry, like other metalforming industries, is experienced based. Success comes largely from trial and error, and the accumulated skill of the artisan. Over the years, this experience has been accumulated into various die design handbooks published by national forging industry associations. However, it is still true that the success of a particular forging design depends greatly on the skill and experience of the die designer. Companies with less experienced designers will require a longer

EXHIBIT 5.1
FORGING PROCESS VARIABLES

Significant Variables in a Deformation Process

Billet Material

- Flow stress as a function of strain rate, temperature and microstructure (constitutive equations)
- Workability as a function of strain, strain rate, temperature and microstructure (forming limit curves)
- Surface conditions
- Thermal/physical properties
- Initial conditions (composition, temperature, history/microstructure)
- Effect of changes in microstructure and composition upon flow stress and workability

Tooling

- Geometry of tools
- Surface conditions
- Material/heat treatment/hardness
- Temperature
- Stiffness and accuracy

Conditions at Tool-Material Interface

- Lubricant type and temperature
- Insulation and cooling characteristics of the interface layer
- Lubricity and friction shear street
- Characteristics relatec to lubricant application and removal

Deformation Zone

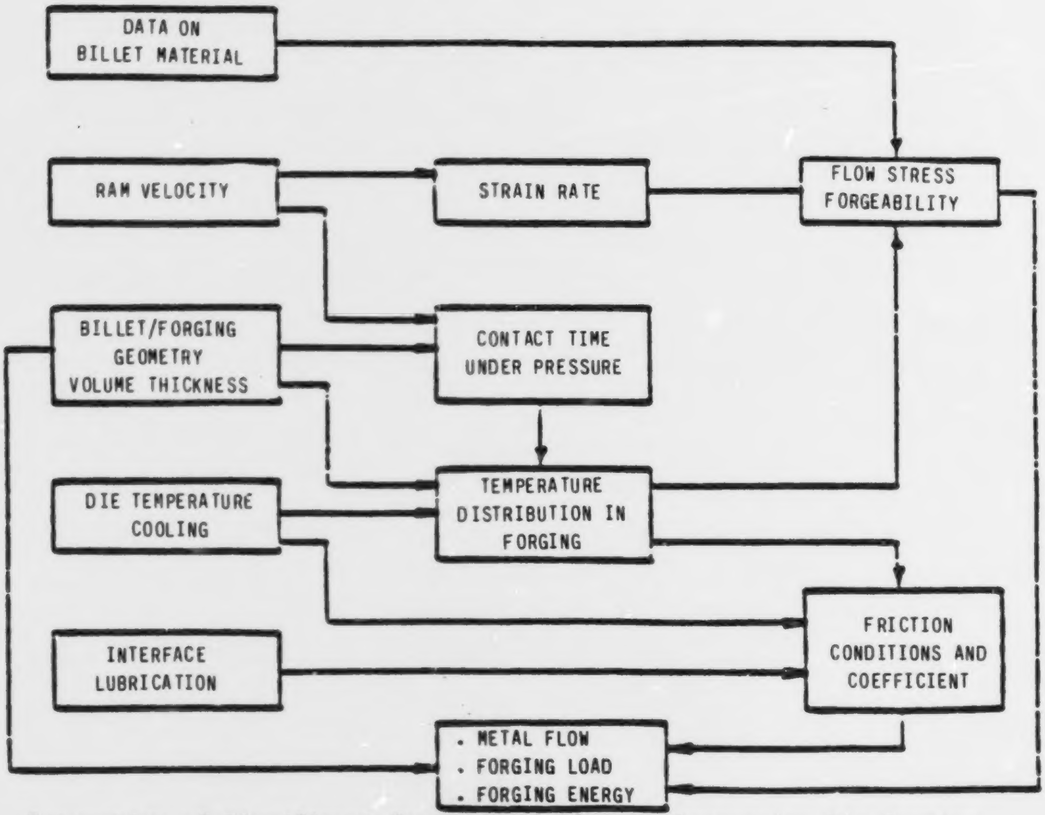
- Deformation mechanics, model used for analysis
- Metal flow, velocities, strain rates, strains (kinematics)
- Stresses (variation during deformation)
- Temperatures (heat generation and transfer)

Equipment Used

- Speed/production rate
- Force/energy capabilities
- Rigidity and accuracy

Product

- Geometry
- Dimensional accuracy/tolerances
- Surface finish
- Microstructure, mechanical and metallurgical properties



Interation of Significant System Variables in Impression Die Forging

Source: After T. Altan
Batelle Labs.

period of time to design a die, and more extensive series of die try-outs than companies with more experienced designers. Computer-aided design is therefore the only method available to reduce the requirement for experience and to speed up the entire die design process.

The development of computer-aided engineering systems for impression die forging must have as its starting point, an understanding of the interaction of the system variables. In the case of impression die forging, these variables are material related, tool related and process related. For example, the direction of metal flow, the magnitude of deformation, and the temperature greatly influence the properties of the forged component. The metal flow determines the mechanical properties related to local deformation, and the formation of defects such as cracks or folds at the surface or inside. The local metal flow is in turn influenced by the process variables such as temperature, energy of deformation, and dwell time. Exhibit 5.1 illustrates these variables and their interaction.

5.2.1 Canada

There was only one Canadian forging company with an operational CAD/CAM system in 1984. This was the CGE plant in Bromont, Quebec. Two companies - TRW Thompson Products and General Motors - will be installing systems in 1985. These systems will be used almost exclusively for drafting of the die designs. It is expected that post processors for NC tape preparation will also be utilized. The systems will not be used for analysis of die design alternatives. Die design remains largely the secret of the die designer.

The Canadian General Electric turbine blade plant in Bromont, Quebec, makes very extensive use of CAD/CAM and CNC technology for die design, die manufacture, and forging and machining operations. The plant is an excellent example of the full use of modern production methods and computer technolcgy. It is one of the few examples in Canada of the complete implementation of computer integrated manufacturing (CIM) technology.

Die manufacture in Canada is accomplished by a variety of means. Although all forging companies in Canada have EDM equipment, it is not employed in the manufacture of all dies. Standard milling machines, CNC milling machines, copymills and other types of machine tools are also used. It is estimated that approximately 50% of forging dies are manufactured by EDM techniques, while the balance are milled using either conventional or CNC machines. Most forging companies manufacture substantially all of their die requirements. The exceptions are some of the small ferrous forging companies, and the only aluminum forger in Canada. Contract die makers generally use EDM techniques to manufacture forging dies.

Trimming dies are made by a combination of conventional and EDM methods, with conventional machining being by far the most popular method. Most forgings are hot trimmed.

Flood welding of die blocks is now common in most Canadian forging plants. Very little use of inserts is made, except for shrink fitted cold forging dies. Flood welding offers a number of features to the forge plant, chief of which are:

. extended die life
. ease of repair.

Most hammer and press forging dies are not locked to prevent mismatch.

5.2.2 United States

U.S. forging companies produce approximately 70% of their forging die requirements and approximately 67% of their trim die requirements. Die manufacture is similar to Canada, with both EDM and milling machines being employed. A 1982 survey of the forging industry reported the following incidence of use for die making equipment:

. EDM	31% of plants,	1,200 machines
. Duplicating Mills	28% of plants,	690 machines
. Hobbing	3% of plants,	30 machines
. N/C mills	14% of plants,	340 machines

The relatively low level of utilization of modern die making equipment such as EDM and N/C is partially attributed to the low level of new die requirements. For example, in the 1982 survey referred to above, 75% of forging companies required less than 100 new die sets per year. Only 10% of plants used more than 500 die sets per year. Obviously, forging plants have found it uneconomic to utilize EDM or N/C machines to manufacture a limited number of dies.

The use of cast dies for finishing operations in mechanical presses is very limited. Cast dies have proved to be of economic use in high volume production of press forgings. Captive automotive forge plants represent the largest users of cast dies for finish forging. Cast dies have been used more often for trimming and coining operations.

In contrast to Canada, less use of welded dies was observable in the United States. Inserts were employed more often than in Canada for finishing of hammer forgings. Fixturing of die inserts was generally accomplished by means of angled keyways and dowels.

The application of CAD/CAM to forging die design and manufacture is very limited. The largest forging companies and those companies involved in aerospace forgings have begun to install systems. These systems have been utilized primarily for automated drafting, rather than analysis of the forging design. The general feeling in the industry is that CAD/CAM systems for forging operations are too expensive at present to use for most common forgings. Where CAD/CAM systems have been used, as at Eaton Corp., the following benefits have been achieved:

- better understanding of the interaction of die design and process variables;
- reduction in material consumption;
- reduction in die design time;
- improvement in tolerances achieved over conventional methods.

It is expected that CAD/CAM for die design and manufacture will not become commonplace in the U.S. forging industry until system costs can be reduced to less than $50,000.

5.2.3 Japan

Die design and manufacture practices in Japan are quite similar to those employed in North America, with the following execptions:

- EDM and CNC milling is more common in Japan than in the United States or Canada;
- EDM tends to be by use of copper electrodes, rather than graphite electrodes;
- flood welding is not used as much as in Canada. Most die impressions are resunk into planed die blocks.

CAD/CAM use in the Japanese forging industry is very limited. Only two companies interviewed for this study had such systems. These were used for the design of forging rolls and for the drafting of die designs. There was no capability to generate NC instructions for the machining of the rolls or the dies.

Trim dies are generally made using EDM, with a relatively narrow band on the cutting face. Most trim dies were of the multiple type. Hot trimming was the normal procedure, although for hand tools and small articles, cold trimming was also employed.

5.2.4 Europe

European die design and manufacture is also similar to that employed in North America. The use of EDM and CNC equipment is quite widespread, even small forging plants. Conventional milling machines and copy mills are also in widespread use.

The use of CAD/CAM systems for design and manufacture of forging dies is quite limited in Europe. For example, there is only one forging company in Sweden with a CADD system, although one other company will be installing a system in 1985. The main use of the system will be for drafting of forging designs. These are reported to be only 3 CADD systems in German forging plants. No CADD systems are known to be in operation in the French Forging industry.

The use of CADD in the U.K. forging industry is currently restricted to two companies. GKN has used CADD for the optimization of forging design, rather than die design, to obtain a finite service life. Service loads are measured and this data is then used in finite element analysis. The results of the procedure can be very significant. For example, the technique resulted in weight savings of 20% for an axle beam and a reduction of 23% in forged weight and 14% in finished weight for a connecting rod.

The second CADD installation in the United Kingdom is at Doncaster Monk Bridge. This company forges finished envelope turbine blades. The CADD system processes design data received in tape format from the jet engine manufacturers. This data is plotted and displayed on a screen to check its integrity. The computer is programmed to identify data which does not meet the form of the calculated curve. The data is not used to generate tapes for N/C machining of EDM electrodes or die impressions. These are prepared separately.

The use of flood welding in place of die inserts is not as widespread in Europe (except for the United Kingdom) as it is in Canada. Inserts for both hammer dies and press dies are still widely employed. Inserts may be fixed either by key ways and dowels or shrink fitted. Die locks are commonly used in all European forging plants to assist in preventing mismatch. This is believed due to two factors:

- much more widespread use of counterblow hammers, and the requirement to guide two sets of rams and dies;

- the use of drop hammers in which the side frames are fixed on the anvil and ram guide adjustment is made at the guides.

Most trim work is done in the hot state in Europe. Trim dies are generally made by EDM or N/C machining.

No use of cast dies was observed, although it is believed to be a fairly common practice in Germany.

5.3 Shearing/Sawing

Forging stock must be cut from the initial mill product prior to forging. Regardless of the method of cutting the stock, the mill product must be brought from storage. In most forging plants forging stock is stored out doors and segregated by shape, size, and alloy. Shops forging valuable materials, or materials subject to rapid surface deterioration will store materials inside, sometimes in quarantined areas. Retrieval of material from storage is generally by fork lift or by overhead crane. Some high volume forging shops, particularly those forging automotive components or those using Hatebur type machines, store forging stock directly behind the shear or saw. In this case, bar unscramblers will be used to feed bar stock to the shear, saw, or automatic forging machine. An indexing mechanism will be utilized to control the slug cut-off to yield slugs of uniform dimensions and weight.

Large stock in excess of 10" (254 mm) cross section must be sawn. Saws may be of the circular, band, or reciprocating design. Sawing speeds are dependent on a variety of factors related to the physical properties of the stock, the nature of the lubricant, and the design and material of the saw blade. In general, sawing speeds are considerably slower than shearing speeds, but offer the advantages of a cleaner cut face and better precision in terms of cut length. Recently, a new type of saw has been developed which utilizes an electric arc assist. Saws using laser assist are also available. The saws can be computer controlled. Cutting rates of up to 280 square inches of cross section per minute for materials ranging from low carbon steel to tool steel to titanium and superalloys have been reported.

The development of computer controls for automatic gauging of billet size and weight for precision shearing or sawing is not well established. Few companies have installed such equipment. The use of automatic storage and retrieval systems (AS/AR) is also rare. On a region-by-region basis we can note the following with respect to raw material storage and stock preparation technology.

5.3.1 Canada

Almost all ferrous forging stock in Canada is sheared. Forge diameter bar and billet stock is generally hot sheared using Buffalo shears. Material is passed through the forge shop wall to the shear. Slug size is controlled by a mechanical indexing system. Cold shearing procedures are very similar. Non-ferrous materials such as copper and brass are stored indoors and are sawn or cropped to size. Aluminum forging billets are received as precision cut billets. Slugs for cold forging are precision sawn.

Inside storage of material is common only for wire rod material and for material to be processed by Hatebur type machines. Some of the larger forging companies such as Thompson Products employ inside storage for all their material. All forging companies employ tote bins and fork lifts to move slugs from the shear to the furnace or induction heater. Wire rod is processed directly by cold heading machines.

5.3.2 United States

Raw material storage and handling is very similar to that found in Canada. Outside storage is predominant, although companies specializing in cold forging, non-ferrous forging, or production of fasteners will use inside storage. Incoming inspection procedures are generally limited to a visual check for size and appearance, weighing, and check of mill certification. Shearing and sawing are employed about equally. No laser gauging or electronic weighing system were identified which were used to monitor slug dimensions and weights.

Cold shearing is predominant and is used in some instances even where hot shearing would normally be used. Sawing is restricted to large diameter ferrous material or non-ferrous materials. Bar unscramblers are not generally used. The following data provides information as of 1982:

	% Plants With	Total Number
Bar unscramblers	13%	250
Billet saws	46%	1,200
Billet shears	46%	1,100

5.3.3 Japan

Raw material storage in Japan is generally located outside, but under limited cover. Relatively little material is stored directly inside forging plants. One of the key distinguishing features of the Japanese forging industry is the low level of inventories. Most companies receive material on a weekly basis, and aim for only one or two weeks inventory of material. For example, one typical plant visited maintained an average inventory of only 10,000 pounds of material, despite an annual production of 600,000 pounds of finished forgings (hand tools). Incoming inspection of raw material is restricted almost completely to checking of mill certifications. Raw material returns to the mills amount to less than 0.1% of purchased tonnage for the Japanese forging industry.

Cold shearing is by far the most common method of preparing slugs. Only one company, a producer of large impression die and open die forgings, reported using only hot shearing. Of the twelve companies interviewed for this study, only five reported using hot shearing, and only for about 20% of their requirements. Only two companies reported the use of electronic gauges to monitor slug size and weight. One of these companies reported that their system was not practical for regular production use, while the other used the system for only a portion of its production requirements.

5.3.4 Europe

Raw material storage and preparation practices in Europe are not much different from those employed in North America. Incoming inspection of ferrous forging stock is generally limited to verification of weights, sizes and mill certification against purchase orders; and visual inspection of stock for surface defects. Very little analytical testing of material to confirm metallurgical, chemical, or physical properties of the stock is carried out, except when requested by the customer.

Shearing technology is very similar to that in North America. High production plants such as the captive automotive forging plants utilize bar unscramblers and automatic indexing units. Smaller companies rely on manual feeding of bars to the shear or saw. Throughout Europe, the emphasis in shearing or sawing was on achieving a clean cut face on the slug. Slugs were invariably handled by tote bins. Most shearing was done cold.

Inventories of raw materials in European forge shops were comparable to those in North America and considerably above the levels typical of Japanese forging plants. Average inventory turns for ferrous stock would range from 6 to 10 times in Europe and North America versus at least 20 times in Japan.

5.4 Billet Handling and Heating

This section of the report discusses billet (slug) handling and heating practices in the forging industry. Traditionally, the forging industry has been characterized by a high level of manual labour to transfer forging stock from shear to furnace to forge. Mechanisation of the industry has been slow, but this is now changing, as will be examined in the following discussion.

5.4.1 Canada

Slug handling and heating practices in the Canadian forging industry are quite traditional but generally on a par with those found in the United States, Europe, and Japan. Transfer of slugs from the shear to the furnace is effected by tote bin and fork lift truck. There is no use of AGVs or rolling conveyors to move tote bins. Cold forging plants employ similar methods.

Exceptions to the foregoing are those companies making fasteners or using automatic hot forming machines such as the Hatebur. In these cases coil or bar stock is fed directly into the machine.

The Canadian forging industry continues to rely predominantly on oil or gas fired slot and box furnaces. However, induction and resistance heating methods are gaining in popularity, especially in press forging. Rotary hearth furnaces are used to a limited extent. Exhibit 5.2 details the distribution of heating facilities in the Canadian ferrous forging industry as of 1979. The non-ferrous forging industry uses gas and gas/oil slot furnaces for most of its requirements. Rotary furnaces and induction furnaces are being considered by some companies.

Feeding of billets into the furnaces is accomplished by a variety of means. The typical mechanisms are:

- Manual load and unload of slot and box furnaces. This is by far the most common method.
- Manual load and automatic unload of walking beam box furnace.
- Manual load and automatic unload of rotary hearth furnace.
- Automatic indexing of slugs from a storage bin and automatic feed and unload from an induction heater. This method is employed only with press forging.

Temperature control of furnaces is generally rudimentary. Very little use is made of energy conservation measures such as ceramic fibre insulation for slot or box furnaces. Induction heaters are more thermally efficient and control of temperature is easier to achieve, but here also there

EXHIBIT 5.2

STEEL HEATING FACILITIES

CANADA

1979

TYPE OF UNIT	NUMBER OF COMPANIES	NUMBER OF UNITS
Oil-fired slot	7	80
Gas-fired slot Furnace	13	65
Combined gas and oil Fired slot furnaces	1	3
Electric induction heating	8	58
Oil-fired box furnace	0	0
Gas-Fired box furnace	6	8
Rotary hearth furnace	3	8
Other	3	4

Source: Department of Industry Trade & Commerce
Canada Ferrous Forging Industry Study, 1979

are deficiencies. The forging companies interviewed for this study indicated a need for better thermocouple and infrared pyrometer systems to more closely regulate furnace temperatures.

Preparation of slugs for cold forging involves descaling, annealing (sometimes), and lubrication. In most cases descaling is accomplished on the bar prior to shearing. Pickling and lubrication with either a stearate/zinc phosphate or MoS_2 coating is normally done on an automatic basis. Typically, the zinc phosphate coating will be applied by means of a transfer line using an overhead conveyor to move baskets of slugs from tank to tank. Feeding of lubricated slugs to the press is generally handled by means of a bowl feeder mechanism to orient the slugs, followed by a cam activated pickup mechanism or gravity feed to the first forming station.

5.4.2 United States

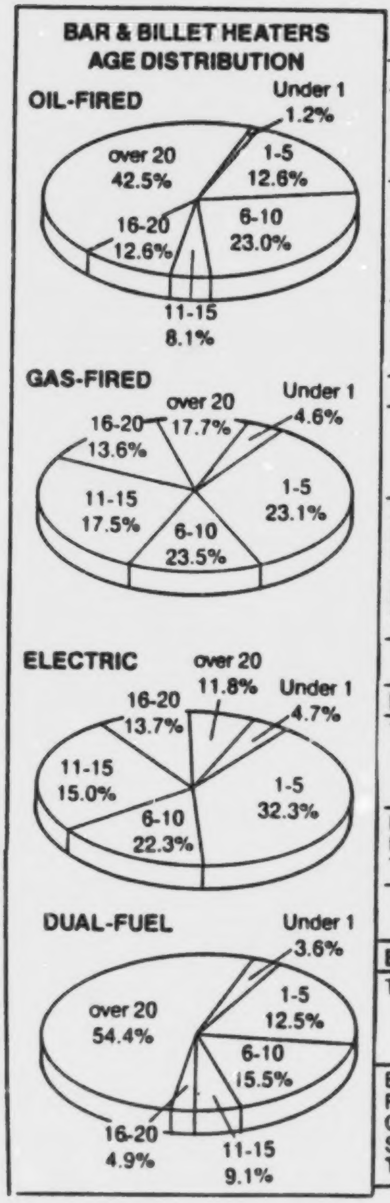
Billet handling and heating practices in the United States forging industry are similar to those in Canada. However, based on published data and plant visits, the use of induction and resistance heating in the United States is less than in Canada.

Billets are generally transferred by tote bin from the shearing operation to the billet heater. Hammer and upset forging operations are generally serviced by box or slot furnaces, with the machine operator or his helper responsible for loading stock into the furnace. Some plants utilize rotary hearth, continuous belt or pusher type furnaces to provide semi-automatic discharge of the furnace.

Mechanisation of billet heating is much more widespread where press forging operations take place. Induction or resistance heaters are generally used. These furnaces are generally equipped with automatic discharge by conveyor. Some furnaces have automatic feeding mechanisms. There is a limited use of robots for feeding furnaces. These applications will be discussed in a subsequent section.

EXHIBIT 5.3

U.S. FORGE HEATING EQUIPMENT


BAR & BILLET HEATERS AGE DISTRIBUTION

BAR & BILLET HEATERS—OIL FIRED

Type	Now installed			
	No. of plants	No. of heaters	Average/ plant	Projected ind. total
Box	8	91	0.6	510
Rotary hearth	3	6	0.0	30
Slot	13	120	0.8	680
Pusher	1	1	0.0	10
Total	**21**	**218**	**1.4**	**1200**

BAR & BILLET HEATERS—GAS FIRED

Type	Now installed			
	No. of plants	No. of heaters	Average/ plant	Projected ind. total
Box	41	268	1.7	1500
Rotary hearth	13	26	0.2	150
Continuous belt	12	62	0.4	350
Slot	26	168	1.1	950
Pusher	7	21	0.1	120
Total	**77**	**545**	**3.4**	**3100**

BAR & BILLET HEATERS—ELECTRIC

Type	Now installed			
	No. of plants	No. of heaters	Average/ plant	Projected ind. total
Induction	67	347	2.2	2000
Resistance	21	106	0.7	600
Total	**79**	**453**	**2.8**	**2500**

BAR & BILLET HEATERS—DUAL FUEL

Type	Now installed			
	No. of plants	No. of heaters	Average/ plant	Projected ind. total
Box	16	126	0.8	710
Rotary hearth	5	21	0.1	120
Continuous belt	1	2	0.0	10
Slot	23	160	1.0	900
Total	**32**	**309**	**1.9**	**1700**

Source: Precision Metal, Nov., 1982

Data on the number and age distribution of bar and billet heaters in the United States is provided in Exhibit 5.3.

Slug preparation and handling procedures for cold forging are identical to those used in Canada.

5.4.3 Japan

The Japanese forging industry utilizes a wide variety of billet handling and heating equipment. In most cases sheared billets are moved by tote bins to the furnace. Some shops shear at the forging machine and use induction heaters while others use very traditional methods. Based on the results of the survey, oil fixed slot and box furnaces would appear to be the most popular heating method, followed by induction heating, and gas fired slot furnaces.

Energy conservation is a particular concern of the Japanese forging industry. Data obtained during the survey provided the following information regarding energy consumption.

Furnace Type	Range of Energy Use
Oil fired slot	2,700 kcal/kg - 6,111 kcal/kg 0.093 l/kg
Gas fired slot	1,790 kcal/kg - 3,000 kcal/kg
Induction	0.47 KWH 1 kg - 1 KWH 1 kg
Resistance	540 KW/kg - 589 KW/kg

A good example of the energy conservation measures undertaken in Japan was described at the 1983 International Drop Forging Conference. The examples cited by Tokyo Drop Forge Co. included the following:

- use of ceramic fibre lining in a gas fired furnace, resulting in fuel consumption savings of 7%;

- use of a recuperator on a rotary hearth furnace, yielding 20% fuel savings;

- reduction of forging temperature by 20 degrees C in an induction heater, reducing power consumption from 425 to 418 KWH/tonne of steel.

5.4.4 Europe

The range of billet handling and heating technology employed in Europe is very wide. There are several extremely modern facilities with fully automated shearing/transfer/induction heating/forging lines as well as a large number of labour intensive hammer forge shops utilizing highly energy intensive processes. The most typical arrangements utilized were:

- drop hammer shops
    - manual load/unload of slot and box furnaces
    - some use of rotary hearth furnaces
    - very limited use of induction and resistance heaters, if used, they are loaded manually.

- upset and counterblow hammer shops
    - similar to drop hammer shops.

- press forging shops
    - induction/resistance heaters predominate, often with automated furnace load/unload functions
    - limited use of rotary hearth furnaces, but often equipped for automatic load/unload.
    - limited use of rotary hearth furnaces, but often equipped for automatic load/unload.

- cold forging shops
    - extensive use of vibratory feeders and cam actuated or gravity unload mechanisms.

5.5 Forming Operations

In this section of the report we discuss the nature of existing forming plant operations. Particular attention is paid to the application of advanced forging technology in each region under study.

5.5.1 Canada

The Canadian forging industry, given its relatively small size, operates a wide range of well maintained equipment. The 1979 equipment inventory of the ferrous forging industry is detailed in Exhibit 5.4. Since 1979, some of the hammers have been replaced by presses, while new forging operations have also installed mechanical presses. The non-ferrous forging industry uses mechanical presses for the forging of copper-based materials. Mechanical and hydraulic presses are used for forging aluminum.

There is no current data available on the age distribution of forging equipment in Canada. In general, though, drop hammers are at least 20 years old. Many are of pre-war vintage. Mechanical and hydraulic presses are generally in the 10-20 year age category, with some being of recent vintage. Coining and trim presses are also mainly in the 10-20 year age category.

5.5.2 United States

The United States forging industry consists of a wide range of companies from small hammer shops to highly automated shops producing very sophisticated forgings. The diversity of operations makes direct comparisons with the Canadian industry difficult. However, the following general comparisons can be made:

EXHIBIT 5.4

FORGING PRACTICES EMPLOYED

CANADIAN FERROUS FORGING INDUSTRY

1979

TYPE OF UNIT	NUMBER OF COMPANIES	NUMBER OF UNITS
Gravity drop hammer	11	102
Power-assisted drop hammer	9	46
Mechanical Press	10	42
Hydraulic press	5	9
Upsetting	12	71
Cold forging	3	15
Ausforging (warm forging)	0	0
Roll forging	10	31
Coining press	10	38
Trim Press	17	199

Source: Industry, Trade & Commerce Study

- hammer operations are more prevalent in the U.S. than in Canada
- the use of flood welding of dies is more common in Canada than in the United States
- robots and manipulators are more widely employed in the United States than in Canada
- the defence and aerospace markets in the United States have made a significant contribution to the promotion of U.S. forging technology in terms of:
  - forging methods
  - metallurgy
  - heat treatment methods
  - quality control
- the non-ferrous forging industry in the U.S. is significantly larger than in Canada.

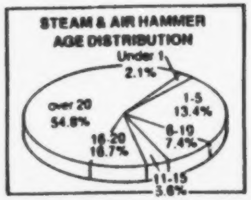
The U.S. forging industry operates with much the same equipment as the Canadian industry. Exhibit 5.5 illustrates the population and age distribution of U.S. forging equipment. As can be seen, much of the equipment is of relatively ancient vintage. In recent years some forging companies have rebuilt their equipment and installed electronic controls and/or modified the operating mechanisms of the unit to improve blow efficiency and reduce energy consumption. As previously mentioned, the range of technologies employed in the U.S. forging industry is very diverse. The captive automative forge plants such as Ford in Canton, Ohio, are highly automated and represent a very high level of productivity. These companies make extensive use of induction heating, conveyors, mechanical presses with automatic workpiece transfer, and in-process quality control using ultrasonics and other NDT methods.

Other companies, principally those servicing the defense and aerospace industries, are oriented to small lot production. Companies such as Park Ohio, Alcoa, and Ladish produce small batches of high value forgings using steam hammers, hydraulic and mechnical presses and counterblow hammers.

EXHIBIT 5.5

U.S. FORGING INDUSTRY EQUIPMENT

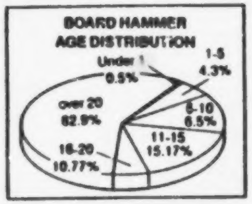
1982



STEAM & AIR HAMMERS

Size (pounds)	Now installed			
	No. of plants	No. of hammers	Average/ plant	Projected ind. total
Less than 1000	5	13	0.1	70
1001-5000	58	268	1.7	1500
5001-10,000	27	59	0.4	330
10,001-25,000	15	36	0.2	210
over 25,000	4	8	0.1	50
Total	78	386	2.4	2200

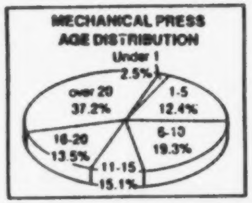
Based on 160 responding plants



BOARD HAMMERS

Size (pounds)	Now installed			
	No. of plants	No. of hammers	Average/ plant	Projected ind. total
Less than 1000	11	25	0.2	140
1001-5000	32	194	1.2	1100
5001-10,000	3	4	0.0	20
10,000-25,000	2	4	0.0	20
Total	38	227	1.4	1300

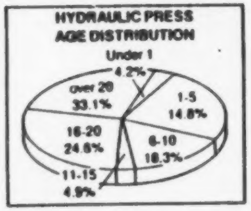
Based on 160 responding plants



MECHANICAL PRESSES

Size (tons)	Now installed			
	No. of plants	No. of presses	Average/ plant	Projected ind. total
100-500	30	155	1.0	870
501-1000	33	58	0.4	330
1001-2000	25	69	0.4	390
2001-5000	29	81	0.5	460
5001-10,000	6	9	0.1	50
over 10,000	2	2	0.0	10
Total	78	374	2.3	2100

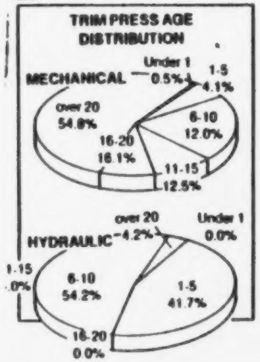
Based on 160 responding plants



HYDRAULIC PRESSES

Size (tons)	Now installed			
	No. of plants	No. of presses	Average/ plant	Projected ind. total
100-500	21	72	0.5	410
501-1000	17	34	0.2	190
1001-2000	21	25	0.2	140
2001-5000	14	22	0.1	120
5001-10,000	4	4	0.0	20
over 10,000	5	5	0.0	30
Total	54	162	1.0	910

Based on 160 responding plants



TRIM PRESSES—MECHANICAL

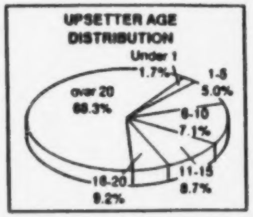
Size (tons)	Now installed			
	No. of plants	No. of presses	Average/ plant	Projected ind. total
50-200	88	686	4.3	3900
201-300	28	134	0.8	750
301-400	17	47	0.3	260
over 400	18	36	0.2	200
Total	96	903	5.6	5100

Based on 160 responding plants

TRIM PRESSES—HYDRAULIC

Size (tons)	Now installed			
	No. of plants	No. of presses	Average/ plant	Projected ind. total
50-200	3	4	0.0	20
201-300	3	12	0.1	70
301-400	1	1	0.0	10
over 400	2	5	0.0	30
Total	8	22	0.1	120

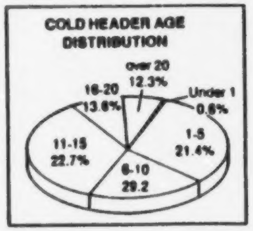
Based on 160 responding plants



UPSETTERS

Size (in.)	Now installed				Plan to buy by end 1983	
	No. of plants	No. of upsetters	Average/ plant	Projected ind. total	No. of plants	No. of upsetters
1/2	1	1	0.0	10	0	0
1	7	9	0.1	50	0	0
1-1/2	13	23	0.1	130	1	1
2	9	26	0.2	150	1	1
2-1/2	4	15	0.1	90	1	1
3-4	23	61	0.4	340	2	2
5-6	14	36	0.2	200	0	6
Total	41	171	1.1	960	4	8

Based on 160 responding plants



COLD HEADERS

Size (in.)	Now installed				Plan to buy by end 1983	
	No. of plants	No. of headers	Average/ plant	Projected ind. total	No. of plants	No. of headers
1/8-1/4	8	100	0.6	580	0	0
1/4-1/2	15	56	0.4	320	3	4
1/2-3/4	12	26	0.2	150	3	8
3/4-1	3	6	0.0	30	0	0
over 1	3	5	0.0	30	0	0
Total	22	193	1.2	1100	4	16

Based on 160 responding plants

Source: Precision Metal
NOV., 1982

Relatively little automation and mechanization is to be found in these plants. However, these plants have also found robots to be highly effective. For example, a major aluminum forger has installed robots in its truck wheel forging line. The robots work in conjunction with a 6,000 ton and a 2,500 ton press. The forging crew size was reduced from 12 to 3 persons and productivity increased from 700 pieces per shift to 1,500 pieces per shift.

The use of quick die change procedures in the U.S. forging industry is extremely limited. Die change times are equivalent to those in Canada, i.e., from approximately 2 hours for small drop hammer dies to 8 hours and more for large dies. Moreover, few forging companies in either the United States or Canada have standardized their tooling and auxilliary equipment such as trim presses.

One company which has developed a quick die change procedure for a mechanical press is Meadville Forging in Meadville, Ohio. This company found that by using a relatively simple procedure, it was able to reduce die change time from several hours to approximately a half-hour. This time saving did not include provision for preheating of the dies. The company developed is procedures from a systems viewpoint, and prior to finalizing its die change procedures, standardized all the tooling and trim presses. Precision forging operations, and processes such as isothermal forging are restricted to the operations of large forging companies such as Wyman-Gordon, Alcoa, Ladish, etc. These companies have highly sophisticated equipment and facilities. For example, Wyman-Gordon manufactures sophisticated aerospace forgings using its own VAR titanium ingot and Hot Isostatic Pressings (HIP). The company also operates a fully automated isothermal forging plant and a highly automated plant producing diesel engine crankshafts.

Cold forging operations in the United States are highly automated. Most companies utilize precision shears for slug cut-off. These shears are generally capable of tolerances of ± .004" on slug length. Slug preparation is also automated, with most companies employing an overhead travelling bin system to clean the slugs and apply a stearate/zinc phosphate lubricant. One company, Braun Engineering, has developed a different system for applying a MoS_2 lubricant to the slugs. This system operates as follows:

- preheat slugs in non-oxidizing furnace
- apply MoS_2 coating as a water dispersion
- dry burnish at 120 degrees C

The process is handled within a single machine. Production capacity is 9,000 kg per hour. The machine has resulted in overall cost savings of 50% for stock preparation and lubrication.

5.5.3 Japan

The Japanese forging industry, as previously described, is divided into two major sectors. These are:

- large open die forging companies with their own steel making plants. These companies are generally part of one of the major Japanese steel companies;
- smaller, impression die forgers and fastener manufacturers. Many of these companies have very close working and financial relationships with one of the motor vehicle manufacturers in Japan.

These relationships should be borne in mind when discussing the operations of Japanese forging companies.

Forging operations for impression die forging companies are very similar to those in other countries. Much of the equipment used in the plants is of U.S. or European design and manufacture, while other equipment is generally a copy of these designs. The visits conducted for this study provided the distribution of forging equipment as shown in Exhibit 5.6. Except for the absence of fastener manufactures, the plants visited are believed to be generally representative of the range of Japanese forging practices and equipment. The data in Exhibit 5.6 is notable for two items. These are:

EXHIBIT 5.6

EQUIPMENT IN JAPANESE FORGE SHOPS

(12 Plants)

EQUIPMENT	NUMBER	SIZE RANGE
Hammers - gravity	2	60 - 1,500 lb.
- air	59	800 - 15,000 lb.
steam/hydraulic counterblow	1	25m - t
Presses - mechanical	56	200 t - 5,000 t
- screw	9	300 t - 2,500 t
- wedge	1	2,500 t
- hydraulic	11	400 t - 5,000 t
Upsetters - vertical	2	2" - 4"
- horizontal	8	2" - 8"
Extrusion Presses		
- horizontal	3	1,000t - 3,000 t
- vertical	-	
Cold Headers	-	

Plants visited produced: open die forgings
autoparts - captive and non-captive
hand tools
construction equipment parts
aircraft precision forgings
agricultural equipment parts
ranging in size from 0.1 kg. to 40,000 kg.

1) the preponderance of air drop hammers and conventional mechanical presses;

2) the relatively low forging power of most of the equipment.

Most of the forging equipment in Japan is of relatively recent vintage. All of the forge shops visited had excellent housekeeping and were well laid out for efficient materials transfer. Conveyors and other forms of mechanisation are used to a relatively high extent to assist in materials handling.

The use of robots in the Japanese forging industry is limited. Robots, as defined in North America, have found very little use. Rather, the Japanese have used manual manipulators and fixed sequence units to handle and transfer forging stock. Exhibit 5.7 provides some data on the use and number of manipulators and robots in the Japanese forging industry as of 1981.

The incidence of quick die change facilities was also limited. Of the companies visited, only 2 had hydraulic clamping for their mechanical presses, while only 3 had standardized on bolster, bed plate, and die sizes for their hammers and presses. Only two companies reported standardization of ram heights, bolsters, dies, etc. These companies were the two also reporting hydraulic clamping systems. Both of these companies were servicing the automotive industry.

This brief review of typical Japanese impression die forging plants indicates that they operate in much the same way and with much the same equipment as plants in North America. There is, however, one major difference, and that is the willingness of Japanese companies to investigate new processes, and to continually improve existing production processes based on known technology. Two excellent examples of these are the following:

- Mitsubishi Motor Corp.'s development of the cross rolling method for production of axi-symmetric stepped shafts.

EXHIBIT 5.7

JAPAN - 1981

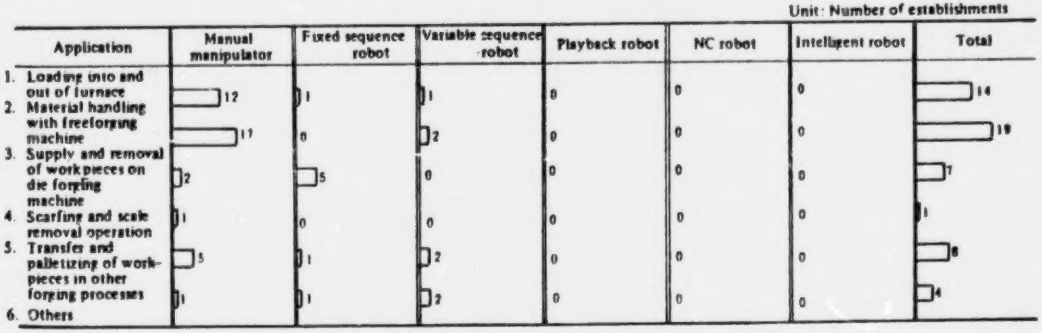
Status of Robot Operations in Forging Process
(71 Establishments)

Type of Robot	Number of robotized establishments	Installation rate (%)	Number of robots installed	Average number of robots per establishment (Note)
a. Manual Manipulator	19	26.8	60	0.85
b. Fixed Sequence Robot	8	11.3	114	1.61
c. Variable Sequence Robot	6	8.5	65	0.92
d. Playback Robot	1	1.4	1	0.01
e. NC robot	0	–	0	–
f. Intelligent Robot	0	–	0	–
Total	30	42.3	240	3.38

Note: These figures include non-robotized establishments.

Application of Robots in Forging Process

Unit: Number of establishments



Application	Manual manipulator	Fixed sequence robot	Variable sequence robot	Playback robot	NC robot	Intelligent robot	Total
1. Loading into and out of furnace	12	1	1	0	0	0	14
2. Material handling with freeforging machine	17	0	2	0	0	0	19
3. Supply and removal of workpieces on die forging machine	2	5	0	0	0	0	7
4. Scarfing and scale removal operation	1	0	0	0	0	0	1
5. Transfer and palletizing of work-pieces in other forging processes	5	1	2	0	0	0	8
6. Others	1	1	2	0	0	0	4

Source: Nomura Research

- Toyota Motors development of a high speed hot roll forming process for the production of helical gears.

Cold forging technology is very similar to that found in North America. Lubrication practices are identical, as are methods for mechanizing the process by use of conveyors, vibratory bowl feeders and cam actuated transfer mechanisms.

5.5.4 Europe

Europe exhibits an extreme range of forging technology from highly computerized systems to systems which can be regarded as blacksmith operations. The main features of the European forging industry are as follows:

- high level of automation, mechanization and use of advanced technology in Germany and Sweden by both large and relatively small companies;

- highly mechanized captive forging industry in France co-existing with an independent forging industry employing traditional technology;

- an extremely wide range of both very sophisticated forging technology and very traditional technology in the United Kingdom, and often within the same company.

Examples of the various technologies employed are detailed below.

5.5.4.1 Sweden

The Swedish forging industry, while small, provides a number of examples of the application of modern forging technology. Among these are:

. Bofors-Kilsta

The Bofors plant is one of the most modern forging plants in the world. The principal feature of the plant is a new forge shop equipped with a 16,000 ton Hasenclever press. The main product produced on the line is large crankshafts of up to 250 kg. and 1,900 mm in length. The plant is completely controlled by computer.

The layout of the plant is illustrated in Exhibit 5.8.

The system is fully computerized and requires only 6 operators. Production speed is 1 crankshaft every 30 seconds for large pieces (200+ kg.) and 1 every 15 seconds for small pieces (80 kg). Die life is approximately 6,000 impressions.

5.5.4.2 Germany/Austria

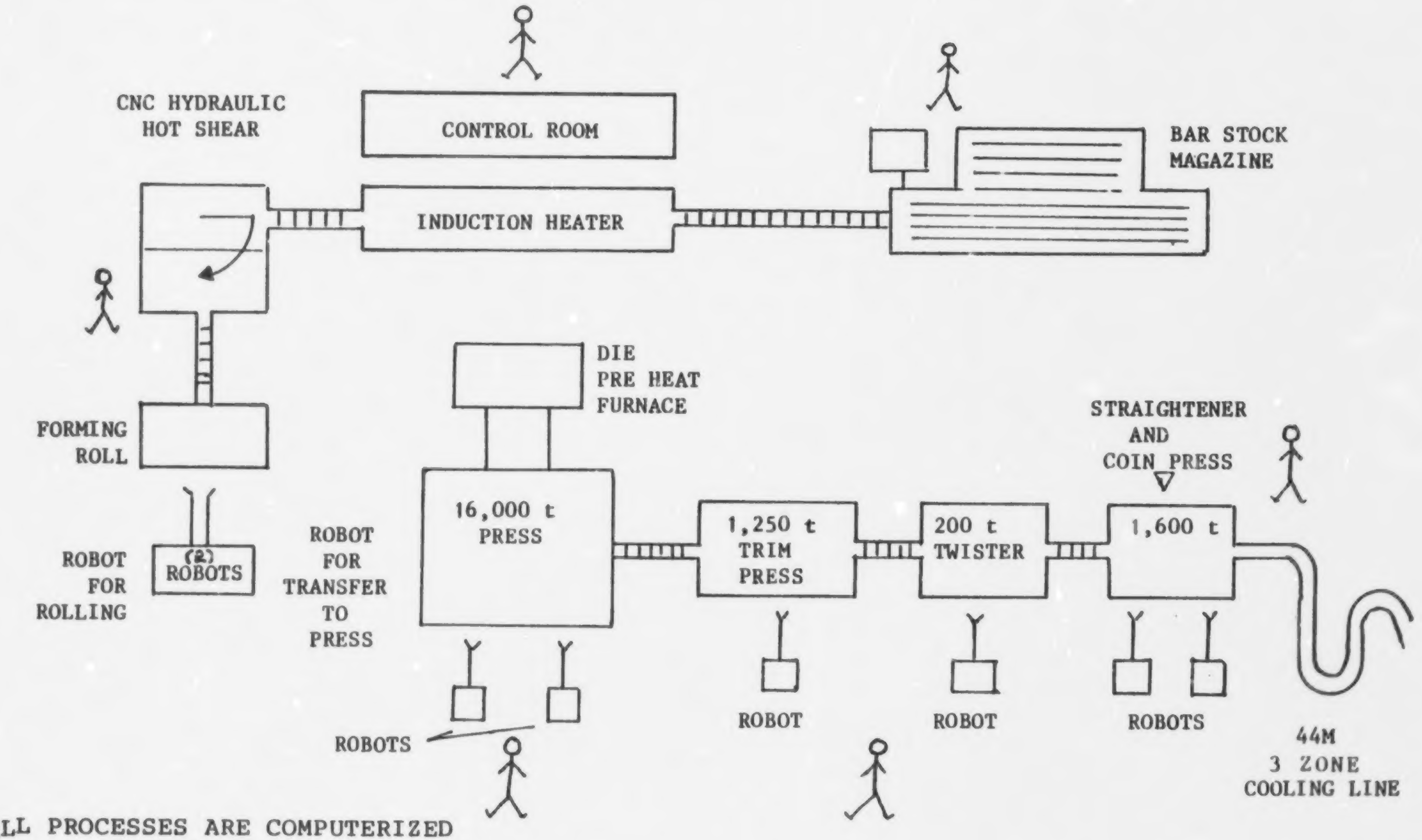
The forging industry in Germany and Austria is very well developed. Several of the major forging equipment companies, such as Eumuco, Lasco, Hasenclever, Siempelkamp, Weingarten and Smith. These companies have been responsible for many of the advances in forging technology in the past 20 years. The German forging industry is often the first to utilize new types of forging machines.

The main features of the forging industry in Germany are:

- extensive use of EDM and CNC equipment for die manufacture;
- extensive use of conveyors and other forms of mechanisation/automation to reduce materials handling.

EXHIBIT 5.8

BOFORS-KILSTA PLANT
16,000 T FORGING PRESS LINE



ALL PROCESSES ARE COMPUTERIZED
USING PDP 11

- high level of use of induction and resistance heating.
- drop forging operations have been largely converted to air and hydraulic hammers or to screw presses;
- counterblow hammers are still prevalent, but mainly of Lasco and Bêché design;
- Lasco hammer presses widely used by shops producing small axle shafts and similar shapes;
- automatic spray lubrication systems are widespread;
- use of flood welding for dies is becoming more widespread, but it is not standard in forge shops. Inserts are still used.
- locking of dies to prevent mismatch is more common in Germany than in Canada. Locking is done by use of round dowels for large forgings or use of bosses and depressions on upper and lower dies;
- friction screw presses appear to be replacing mechanical presses in many applications.

5.5.4.3 France

The French forging industry, more so than in other countries, exhibits an extreme range of technologies between those forgers serving the automotive and aerospace industries, and those serving a broader range of markets. Captive automotive forge shops employ very advanced systems for mechanization and modern forging machinery. Non-captive, non-automotive oriented shops tend to employ very traditional technology. Comments on the technology found in the French forging industry are largely based on review of the literature, as it was only possible to visit two forging plants in France.

The captive forge shops of Renault are reported to be highly automated and to rely totally on presses. A paper presented at the 11th International Drop Forging Congress in 1983 described some of the measures Renault had undertaken to improve die change times on a 45 MN mechanical press. The impetus for the development of the quick die change system was the need to undertake more short run work. The system includes provision for hydraulic clamping, die lifters, and die buggies, and die preheaters.

Another paper presented at the conference described the mechanisation of a drop hammer layout at Forge Stephanoise. This company is a large (900 employees) forging plant producing hammer forgings, precision forgings on a Varipress, and cold forgings for the open market, as well as a line of hand tools. Hammer forged parts range from 0.2 kg. to 250 kg.

The paper referred to above describes the mechanisation of a large hammer layout which had a crew size of 13. The layout was redesigned to make provision for a continuous furnace with automatic discharge, manipulator, and conveyors to reduce the crew size to 6.

5.5.4.4 United Kingdom

The U.K. forging industry exhibited the widest range of technologies. Forging technologies varied from precision net form forging of turbine blades on semi-automatic screw presses to hammer forging on 100 year old gravity hammers. Table 5.1 provides basic information on the age distribution of forging equipment used in British industry:

TABLE 5.1

PERCENTAGE DISTRIBUTION OF FORGING EQUIPMENT

	AGE (years, as of 1982)					
	0-1	1-6	7-12	13-19	20 +	TOTAL NUMBERS
Hot Forge Presses	1%	17%	5%	16%	61%	2,130
Cold Forging Presses	-	43%	6%	27%	24%	263
Hammers - All Types	-	13%	7%	18%	62%	2,201
Forging Machines, Including Rolls	-	25%	3%	18%	54%	549
Cold Headers	5%	8%	18%	26%	43%	1,867
Swaging Machines	4%	25%	22%	25%	24%	1,130
Others -	-	22%	18%	21%	39%	955

As can be seen, the United Kingdom forging industry operates with considerably more hammers than the forging industry in other locations; and also operates with equipment which is generally older than that of its competitors.

The main features of the United Kingdom forging industry are:

- A reliance on slot and box type furnaces, most of which are manually loaded and unloaded.
- A higher proportion of hammer forging than in other countries. Much of the hammer forging is off the bar, rather than cut piece work.
- A high proportion of old equipment, relative to competitors in other countries.
- Less use of CNC and NC machine tools and EDM to mill electrodes and dies than in North America, Japan, or other parts of Europe.

- A well developed aerospace forging industry, employing modern production equipment and methods.

- A technically knowledgeable management, especially in terms of metallurgy.

- Forging plants which tend to be old and poorly laid out in terms of their adaptability to new forging techniques and production methods.

- A lower level of use of automation and mechanisation than in the forging industries of other countries.

- Heat treatment and quality control technology and procedures equivalent to those in other countries.

One of the most interesting aspects of British forging technology is the coexistence in many plants of very sophisticated forging technology and equipment, and very old equipment and technologies. The technical and production management difficulties created by this situation can be severe.

In-process offal and scrap levels in the United Kingdom forging industry appear to be higher than those experienced in North America, Japan, or other parts of Europe. Part of this is attributed to the higher proportion of hammer forging, and thus greater generation of flash. The more widespread use of slot and box furnaces also contributes through loss of material in the form of scale. Finally, in process defects are somewhat higher than in other countries. Defects average 3%-4% in the United Kingdom forge plants, while in Canada, defects average 2%-3% of total production. Defects in the Japanese forging industry are less than 1% of production.

5.6 Lubrication

The traditional forging lubricant for both hammer and press operations has been white graphite. Most forging companies continue to use graphite as it is cheap and well known. The graphite can be applied by hand using a stick, rag or other swabbing device; or applied as a spray, either by means of a manual system or automatically. In hammer forging operations the graphite is almost universally applied by using a rag swab. There are very few spray systems used with hammers. Press forging operations are generally equipped with manual or automatic spray units. Automatic units are always used if the press has been equipped with a transfer bar. In most cases, low pressure air jets are also fitted to the press to blow off scale prior to application of the lubricant. There are very few differences between countries in terms of their use of these systems.

The use of synthetic lubricants is on the rise, but many forging companies report dissatisfaction with the available products. Inconsistent performance and cost are both serious concerns.

In Europe, especially in the United Kingdom, one continues to find sawdust being used as a lubricant in hammer forging of large parts. It is generally applied by the hammersmith helper by hand, and seems to be an effective, although crude system of lubrication. No use of sawdust was seen in North American or Japanese forge shops.

Glass slurries are popular lubricants for upset, hammer and press forgings of materials such as titanium. In fact, glass is the preferred lubricants for titanium upsetting, despite its cost. Other lubricants have been tried but have not been found to be as effective as glass.

Cold forging continuous to rely on the use of zinc sterate/phosphate coatings and MoS coatings for lubrication. No other systems were seen during the course of the study. Almost all companies had automated the slug preparation process to increase throughput.

5.7 Heat Treatment

The range of heat treatment facilities used in the forging industry has already been mentioned. There are few differences in the technologies employed in North America, Japan, or Europe, except for the incidence of use of microprocessor controlled furnaces. Microprocessors are employed very extensively on heat treatment furnaces used for aerospace components. Very sophisticated systems have been installed in the United States and in Europe. Canada and Japan, which lack a significant aerospace forging industry, do not have these systems.

It should also be mentioned that the range of heat treatment facilities available in Canadian forge shops is generally less than that available in shops in the United States, Japan, or Europe. This is believed to be due primarily to the limited range of materials forged in Canada, and the small size of most of the forge plants in Canada.

The major differences in heat treatment practices between North America and Japan and Europe is significantly higher usage of microalloyed nad direct quenching steels outside of North America. As previously mentioned, the trend outside of North America is to use steels which require little or no heat treatment after forging. This saves energy, time, and money for both the forging company and its customer. This philosophy is based on the European and Japanese practice of specifying a material based on its ultimate tensile strength. In contrast, North American designers have specified materials based on yield strength and used elaborate thermal treatments to achieve the desired mechanical and physical properties.

It is likely that microalloyed steel will find increased use in North America in the next few years. If this does happen, forging companies will require much more research on the forming properties of these steels.

5.8 Post Forging Operations and Quality Control

5.8.1 Post Forging Operations

Post forging operations such as finishing machining are rarely undertaken by commercial forging shops. Finishing operations are generally limited to shot blasting or other forms of cleaning. This is especially true in Canada, where no non-captive impression die forging company is known to perform finish machining operations except for producers of plumbing fixtures and engine valves. Captive forge operations such as those operated by General Motors and Canadian General Electric, do perform extensive machining operations on their forged products. Open die forgings exhibit a similar pattern.

In the United States, the situation is somewhat similar to that in Canada. There is, however, more finished machining undertaken by commercial forge shops, especially those primarily oriented to the automotive industry. Such operations are, however, only handled by the larger forge shops. Small commercial forge shops would rarely undertake finish machining operations, except in the case of brass and copper plumbing fixtures.

Japanese forging companies are also very similar to those in North America in terms of their finishing capabilities. The large open die forging companies have extensive finish machining capabilities. Commercial impression die forging companies are rather limited in their machining capabilities. Unless they primarily service the automotive industry. Those forgers producing proprietary products tend to have extensive machining facilities, usually based on transfer line technology.

5.8.2 Quality Control

Quality control procedures in the forging industry centre on two items. These are:

- verification of incoming material
- inspection of forged components.

In most cases, incoming inspection is rather cursory. In North America the general procedures call for:

- verification of mill sheets against purchase order
- weighing
- visual inspection of surface
- dimensional inspection.

Physical, chemical and metallurgical inspection of incoming material is practised on a very limited basis.

In-process inspection procedures are generally limited to random sampling of hot forgings on a non-statistical basis and to hardness testing of finished forgings. Other tests such as Magnaflux, dye penetrant, ultrasonic, eddy current, radiography, etc., are conducted on a much more selective basis, and generally only when specified by the customer. There is very little use of in-line automated non-destructive testing procedures such as laser gauging. The use of coordinate measurement machines in North American forge shops in also very limited. In addition, very few forge shops have instituted statistical process control procedures, although the benefits can be substantial. Exhibit 5·9 illustrates the range of quality assurance facilities in the Canadian ferrous forging industry as of 1980. The U.S. industry exhibits a proportionately similar pattern, except for those companies oriented to the aerospace and defense industries, where elaborate inspection and quality control procedures are required.

Statistical process control (SPC) can have a significant impact on reducing the overall cost of quality in a forge shop. A good example of the impact of SPC is the experience of Teledyne Portland Forge in Portland, Oregon. This company primarily produces gear blanks which are finish machined by the customer. Prior to the introduction of the SPC program, the company was experi-

EXHIBIT 5.9

QUALITY ASSURANCE FACILITIES

CANADA

1980

TYPE OF TESTING FACILITY IN 19 COMPANIES	NUMBER OF COMPANIES
Tensile	9
Impact	8
Bend	6
Hardness	19
Radiography	3
Dye penetrant	18
Ultrasonic	5
Magnetic particle	14
Chemical	6
Spectrographic	4
Eddy current	3

Source: Industry, Trade & Commerce Study

encing an internal defect rate of approximately 1.5% and a customer rejection rate of approximately 0.5%. Since sales were approximately $30 million, the lost profit due to scrap amounted to approximately $600,000.

An SPC programme was introduced to reduce scrap levels. It was determined that flange thickness, hole size and overall diameter were the three critical dimensions for process control. The SPC program resulted in a reduction in total scrap from approximately 3.3% in 1983 to 0.84% in 1984, or a saving of $340,000. The cost of implementing the SPC program was less than $40,000. No expensive CMM equipment was required, as effective process control could be achieved using hand gauges. The SPC program also identified critical process variables and has resulted in changes to the die design tolerances resulting in increased die life. As well, the program has resulted in improved machine maintenance by providing early identification of machine problems such as loose slides or worn crowns. The SPC program has been extended to incoming raw materials and similar benefits are expected.

Quality control in Japan is an obsession. This is easily seen by reference to the average reject rate experienced by Japanese forge companies. The data collected for this study provided the following information:

. average amount of raw material rejected	0 to 0.25%
. average in-process reject rate	0 to 0.5%
. average customer return rate	0 to 0.005%

In contrast, North American forging companies typically experience the following:

. raw material returns	1% - 2%
. in-process rejects	1.5% - 2.5%
. customer rejections	0.5% - 1.5%

A further indication of the process quality superiority of the Japanese forging industry is provided by the experience of Honda. Connecting rods for Honda engines are forged, machined and installed without weighing or mass balancing. General Motors in Canada and the United States must weigh and mass balance the rods after machining to ensure they will be balanced when installed in the engine.

Quality control in the European forging industry is quite similar to that in North America. There is an emphasis on mass inspection of the finished forgings rather than statistical monitoring of the forging process. Overall, the in-process and customer reject rates are similar to those experienced in North America. Some companies such as GKN in the United Kingdom, Bofors and Mercedes-Benz are instituting SPC programs. Forging companies which are not so heavily oriented to the automotive industry tend to have relatively simple inspection and control procedures, and are much more comparable to the average forge shop in Canada. Of course, forging companies oriented to the aerospace and defense industries have extremely elaborate inspection procedures and laboratories, as they must provide full certification on each part.

Throughout Europe there is an increased emphasis on quality control through SPC. The national forging associations and research organizations in Sweden, Germany, France, and the United Kingdom have all instituted education and research programs to upgrade the awareness and application of SPC procedures in their forging industries. The impetus for this has come from the increasingly stringent quality requirements of the automotive industry. It is felt that if the forging industry is to retain or recapture its share of the automotive market, SPC programs will be a necessity.

5.9 Management

The technical and production management skills available in a forge shop have a significant impact on the success of the company. In general, it can be stated that Canadian forge shops employ fewer technically qualified persons than do comparable sized forge shops in the United States, Japan, and Europe. While little hard data is available, one of the major conclusions of the field survey is that Canadian forging companies do not possess a comparable depth and extent of metallurgical and production management expertise to that found in Japan and Europe. To some extent, a similar situation exists in comparison to the United States although the differences are not as pronounced.

In Canada, technical knowledge of metallurgy, forging processes, and heat treatment is generally to be found in only two or three persons within a company. In some of the smaller forge shops the president or general manager is not only responsible for profitability, he also acts as chief metallurgist, chief production engineer and head die designer. Exhibit 5.10 illustrates the manpower distribution in the Canadian ferrous forging industry. The lack of technical depth in the Canadian forging industry is of concern for two reasons:

1. the industry may fail to employ the most modern technology because it is unaware of its existence or is not able to make effective use of it;

2. the industry may not be able to use new materials due to a lack of knowledge of the metallurgical and physical behaviour of the materials during the forging process.

Similar comments can be made with respect to much of the U.S. forging industry. It is only in the large forging companies where one encounters a level and depth of technical expertise similar to that which is typical of even relatively small forge shops in Japan and Europe.

The greater technical knowledge and depth of Japanese and European forging companies enables them to be able to:

EXHIBIT 5.10

CANADIAN FERROUS FORGING INDUSTRY

MANPOWER DISTRIBUTION

FUNCTION	1977 (13 Companies) EMPLOYEES	1977 (13 Companies) % of Total	1978 (15 Companies) EMPLOYEES	1978 (15 Companies) % of Total	1979 (15 Companies) EMPLOYEES	1979 (15 Companies) % of Total	AVERAGE AGE 1979
Managerial	43	2.1	52	2.3	66	2.5	45
Sales & Marketing	30	1.5	35	1.6	44	1.6	40
Technical Staff	53	2.6	69	3.1	77	2.9	41
Clerical	111	5.5	119	5.3	147	5.5	35
Production Supervisory	97	4.8	107	4.8	130	4.9	43
Hammer Operators	149	7.4	164	7.3	222	8.3	39
Forging Press Operators	105	5.2	117	5.2	145	5.4	39
Upsetter Operators	127	6.3	131	5.9	148	5.5	39
Production: All Others	896	44.4	981	43.9	1,139	42.5	39
Maintenance	253	12.5	274	12.3	327	12.2	41
Tool & Die Makers	156	7.7	185	8.3	232	8.7	45
Totals	2,020	100.0	2,234	100.0	2,677	100.0	-

Source: Industry, Trade & Commerce Study

- solve existing production problems more easily;
- evaluate and adopt new forging technologies and processes more easily;
- develop new techniques and procedures in-house;
- understand the forming characteristics of new materials.

The management advantage held by Japanese and European forging companies is most evidenced in the forging of low carbon steels. Japanese and European forgers are generally quicker to develop and utilize new forging technologies and materials than their North American counterparts. It is only in the areas of aerospace forgings, CAD/CAM and powder metallurgy that U.S. companies tend to exhibit technological leadership. The success of U.S. companies in these fields can be attributed to the demands of the U.S. defense industry.

VI - NEW MATERIALS AND PROCESSES

This chapter of the report discusses developments in the metalforming industry related to new materials and processes. The analysis covers developments in both the sheet metal and forging industries, and emphasizes the capability of the metalforming industry to respond to change.

6.1 Sheet Materials

Materials change in the sheet metalforming industry can arise from two main sources. These are:

1) Development of improved products using existing materials. Examples include high strength, low alloy (HSLA) sheet for automotive use and new, corrosion resistant sheet steels.

2) Substitution of other materials for traditional materials. Examples include the replacement of sheet steel by aluminum sheet for car bodies, and the use of composite plastics to replace sheet aluminum in aircraft.

Regardless of the origin of the change, the sheet metalforming industry is faced with the fundamental challenge of learning to respond to the change. In the case of substitution of one metal for another, the problem is primarily one of understanding the forming and other processing properties of the new material. In the case of replacement of metal by plastics, the problem is one of responding to the challenge by:

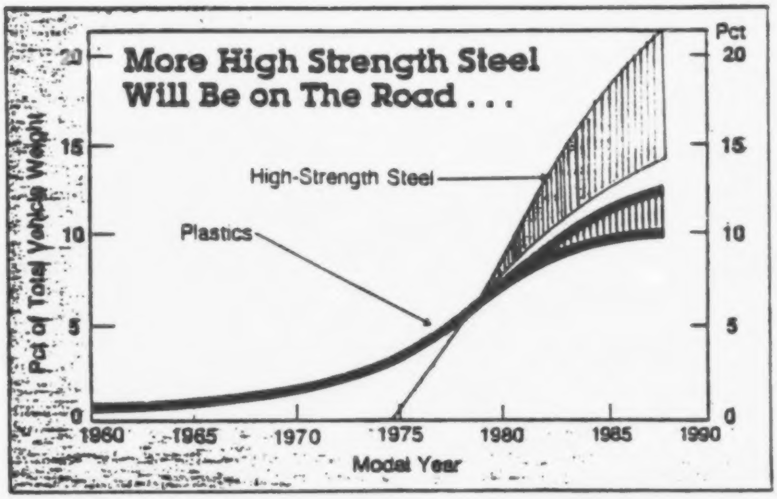
a) developing better, cheaper methods of producing and processing metals to provide equivalent cost and performance to plastics;

EXHIBIT 6.1

MATERIALS USAGE IN AUTOMOBILES NORTH AMERICA

	1983	1984	1985	1986	1987	1988	1989	1990
Ferrous								
High-strength steel	250	256	271	284	307	338	361	385
Cold-rolled steel	525	518	490	471	462	429	405	378
Other steels	795	792	759	707	659	645	647	647
Cast iron	309	323	315	311	311	312	314	314
Nonferrous								
Wrought aluminum	35	36	35	34	35	33	34	34
Cast aluminum	91	97	100	103	102	103	103	103
Magnesium	0	1	1	1	1	1	1	1
Copper/brass	25	25	24	24	22	22	22	22
Lead	24	24	24	24	24	25	25	25
Zinc	10	11	11	11	10	10	10	10
Plastics/elastomers								
Plastic	222	224	223	246	255	257	257	258
Rubber	124	122	119	115	111	110	110	110
Other								
Glass	69	68	67	67	66	65	65	65
Sound deadeners	40	43	42	40	40	42	42	42
Minor materials	49	49	49	51	52	52	52	52
Total	2568	2589	2530	2489	2457	2444	2448	2446

Projections, courtesy Ford Motor Co.



b) developing new metallic materials which offer superior performance.

6.1.1 High Strengh Steels

The challenge of weight reduction in the automobile industry has resulted in a substantial increase in the use of high strength, low alloy (HSLA) sheet steels. These steels offer significantly higher tensile and yield strength levels for a given gauge than do conventional steels. High strength, low alloy steels derive their superior strength and tough properties through the addition of very small amounts of columbium, vanadium and titanium. These elements precipitate out as carbides and nitrides as the steel solidifies and cools. The carbides and nitrides act as "blocks" to the slip planes in the steel, thus increasing the yield strength of the material. The microalloy additions also promote the growth of a fine grain ferritic structure to the steel.

HSLA sheet use in automobiles has expanded significantly in recent years. For example, use of HSLA sheet by Ford Motor was non-existent in 1975. By 1983, the average use had increased to approximately 113 kg. per vehicle. This usage is expected to increase to approximately 175 kg., or 16% of the average vehicle weight by 1990. (See Exhibit 6.1) HSLA found its first application in structural components for cars such as cross members, suspension members, wheels, etc. Newer, more rapidly expanding uses of HSLA are in body components such as body panels, pillars, door beams, etc. and as bumper face bars.

The use of HSLA sheet in the Japanese and European automotive industries has generally been less than that in North America. The imperative to develop smaller, more fuel efficient cars was not as great as it has been in North America. However, this is now changing, especially in Japan. HSLA usage in Japanese cars is expected to increase to an average of 25% of vehicle weight by 1986. The Japanese automotive companies are also very active in exploring increased applications for work hardening and bake hardening grades of steel, especially for exterior body panel applications. European use of high strength steels is also expected to increase, although not for body panel applications.

Two main factors which have limited the rapid introduction of HSLA sheet are the broad spread in tensile properties, and the greater degree of springback in batch annealed steels. Cold rolled HSLA is reported to have inherently lower ductility and lower n values when it is batch annealed than does regular carbon steel of similar tensile and yield strength. Thus, there is more localized necking or thinning and fracture than would be expected from the specified minimum strength level. Variation in springback is also much more severe for batch annealed HSLA. Because of this, tool designers have difficulty in predicting the degree of overcrown that will be required in order to form the part. To overcome this problem, the automotive industry has requested the steel industry to supply material with a strength variation of no more than 10 ksi (68.95 MPa). This requirement is most easily met by a continuous annealing process.

Continuous annealing processes, in addition to their use in producing steels with uniform tensile and yield strengths can be used to produce dual-phase steels. Dual phase steels are steels with controlled percentages of transformation microconstituents such as martensite. By varying the processing parameters, the steel mills are able to produce grades exhibiting excellent formability. After forming, these steels can be passed through a paint oven or other type of thermal treatment to increase the tensile strength of the material.

The development of new grades of high strength steels has resulted in a need for cheap, fast and reliable tests to differentiate the various grades. As mentioned previously, the sheet metalforming industry rarely undertakes more than visual inspection of incoming raw material stock. The industry relies on mill certification as to grade, tensile and yield strength, elongation, and n and r values. This dependence on mill certification is expected to increase, especially in the automotive industry, as Just-in-Time (Kanban) inventory practices, and SPC, become more widely accepted. Current testing procedures are time consuming and relatively expensive. New methods are required which can be employed equally by steel mills, steel distributors, and fabricators which do not require elaborate equipment or highly trained technicians.

6.1.2 Corrosion Resistant Steels

Corrosion protection for automobiles has received considerable attention in the past five years. Most of the major automobile companies operating in North America are now offering perforation guarantees of at least three years. Some companies, such as Chrysler, offer a five-year guarantee. There is now a movement to a 5 year perforation/10 year cosmetic corrosion guarantee system. Such warranty plans can only work if substantial amounts of corrosion resistant material are used. The increase in the amount of corrosion resistant steels used in the automotive industry is reflected in the variety of corrosion resistant steels now available.

The two major problems with the current range of corrosion resistant steels are:

- adhesion of the coating to the forming dies, and flaking of the coating off the substrate;
- welding problems.

Variations in formability are also a concern, as are problems associated with the paintability of the materials. During the course of this study, fabricators in all countries mentioned problems associated with coating adhesion, especially with the use of galvanized steels. Scoring of the dies and retention of zinc flakes on the dies was mentioned as a problem. Loss of zinc from the substrate during severe forming operations was also a problem. Additional data on lubrication systems was felt to be desirable. Other forms of coated steel also experience problems with the adhesion of the coating layer during forming and welding operations. Again, additional data on various lubrication and press systems was desired.

Welding of coated steels, especially two-sided galvanized, has always been a problem. The most serious constraints exist with 2-sided hot dipped material. Galvannealed material, electrogalvanized, electrocoated, and aluminized material offer varying advantages in terms of weldability, but at a loss in terms of other desirable properties such as formability or paintability.

Other forms of corrosion resistant steel, such as terne plate, find only specialized uses such as fuel tanks. Prepainted steels, which have been widely employed in North America, are being replaced by zinc-rich products, as described above. There is, however, some movement toward increased use of material using polyester, vinyl, or urethane elastomeric primers. Again, more extensive information on processing parameters is required.

6.1.3 Plastics

Plastics usage in automobiles has increased substantially in the last five years. The most dramatic examples have been the Pontiac Fiero, the Honda Ballade CR-X, and the Citroen BX. These vehicles utilize plastic body panels to a very high degree. The panels are manufactured using sheet moulding compound (SMC) and reinforced reaction injection moulded (RRIM) in the case of the Fiero. Honda has chosen to use a special blend of ABS and polycarbonate resins which are injection moulded to produce its body panels. This process is reportedly cheaper than the processes used by General Motors. Citroen uses the ZMC injection moulding process. This process incorporates very long (25 mm) glass fibres as a reinforcement.

At the present time, non-structural plastics body panels are only used in limited production cars. The general feeling in the automotive industry is that when production volumes are in excess of 150,000 units, steel will be preferred due to increased processing speeds. Non-structural parts for other vehicle components, such as fuel tanks, radiator fans, inner fender liners, etc., could displace substantial volumes of sheet steel. For example, many European vehicles currently use HDPE fuel tanks and it is likely regulatory approval for their use in North America will be received in the next 2-3 years. Bumpers, which could be considered to be a semi-structural product, have been largely converted to plastic construction. It is likely that there will be no metallic bumpers on most North American passenger vehicles within five years.

Use of structural plastics in automotive applications will be much more limited. Processing and raw material costs are generally prohibitive, at least at present, to permit widespread use. However, a composite wheel is now being marketed which can replace the pressed steel wheel for passenger vehicle use. Other load bearing members are more difficult to convert to plastics. The major applications would be floor pans, cross members and door pillars. These components are difficult to fabricate from composite material at reasonable cost. They also suffer a disadvantage in that they actually are too stiff, and therefore too damage-intolerant, to be used in current automotive designs. In summary, the expected outlook is for non-structural plastic components such as body panels to be fastened to a structural frame of steel. This combination offers significant design flexibility at reasonable manufacturing costs.

6.1.4 Composites for Aircraft

Materials development in aerospace applications is concentrated in the areas of superplastic forming of titanium and aluminum, and the use of composite materials. Composites based on graphite, aramid or other fibres have received a considerable amount of research and interest on the part of aircraft manufacturers. In Canada, both De Havilland and Canadair have made extensive use of composites. Composite applications account for 4.5% of the dry weight of De Havilland's Dash 7 and almost 10% of the dry weight for the Dash 8. Boeing Aircraft of Canada has substantial experience in the design and fabrication of composite plastics for interior uses in aircraft. Other companies in Canada with substantial composite experience include Enheat Ltd., in Amherst, Nova Scotia, and Fleet Industries Ltd., in Fort Erie, Ontario.

Composite developments are well advanced in the United States, where defence applications have been the driving force. Projects such as the Advanced Composite Airframe Program (ACAP) have been instrumental in promoting increased use of composites. Civilian aircraft use of composites has also expanded considerably in the past few years. All composite aircraft such as the Avtek 400 and the Lear Fan are now in the testing stage. These aircraft show substantial weight reductions over comparable conventional aircraft. In addition to the weight savings, composites offer an opportunity to substantially reduce the number of fasteners required, thus resulting in a significant reduction in assembly costs.

Composite development work is also taking place in Japan and Europe. All major aerospace companies are involved in some aspect of composite technology. As in the United States and Canada, work has concentraed on non-structural applications. Now, however, composite manufacturers are examining structural applications such as rudders. It is in these structural applications where the most severe competition between composites and metals is expected to take place.

Much research and development work remains to be done regarding composite applications. The main areas of interest requiring work are:

- automated fabrication techniques for assembly of complex shaped parts;
- automated NDT methods;
- high temperature and fatigue resistant resin and reinforcement systems;
- joining and fastening systems;
- electrical and radio frequency interference problems.

6.2 Forging Materials

The major developments facing the forging industry are:

- microalloyed and direct quenching steels
- powder metallurgy
- new non-ferrous alloys and discrete metal matrix composites
- isthermal forging
- ceramics
- new castings technology

6.2.1 Microalloyed and Direct Quenching Steels

As previously mentioned, the use of microalloyed and direct quenching steels is much higher in Japan and Europe than in North America. These steels offer processing advantages in terms of elimination or reduction of heat treatment requirements. Vanadium treated steels are used where the applicaion does not have severe ductility and/or impact requirements. If ductility is a concern, steels suitable for direct quenching can be used in place of high carbon steels. Microalloyed and direct quenching steels are reported to offer overall process savings of approximately 10% in comparison to standard medium carbon and low alloy steels.

Research in Europe indicates that microalloyed and direct quenched steels suffer only a small deterioration in toughness and durability in comparison to conventional steels. Within the automotive industry the major concern is the room temperature toughness of the forged product.

Other developments in this field are the increased use of continuously cast steels. Concast steels offer scope for raw material cost savings and improved uniformity in physical and metallurgical properties. The use of continuously cast steels has been hindered by concerns over the soundness of the billets, especially when the billets have not been subjected to a prior reduction. In most applications it is believed that at least an initial 4:1 reduction must be used if the continuous cast material is to have properties equivalent to ingot material.

Considerable dispute still exists as to the need for reduction and the overall performance properties of microalloyed and continuously cast steels in forging applications. Research programs in Europe, the United States, and Japan are currently underway to develop performance data for continuous cast steels, as well as for microalloyed steels.

6.2.2 Powder Metallurgy

The use of powdered metals to make components has existed for several decades. Powder metals offer the intrinsic advantage of being shaped to net or near net form. The traditional powder metalforming process involves cold compaction of the powder in a press, followed by sintering. Other processes can be used to improve the tolerances achieved, or the physical properties of the material.

Currently, powder metal components fall into three major market areas. These are:

1. Engineering components such as small gears, bushings, and many other small size parts which are almost all made of ferrous powders.

2. Tools which are made by isostatic pressing of powder which have a high fraction of carbides or other refractory materials.

3. The manufacture of standard shapes, e.g., billets, strip, etc., by consolidation of metal powder.

Of greatest interest to the forging industry is the use of powder metal for the manufacture of engineering components. The automotive industry is by far the largest market, and accounts for some 60% to 70% of all powdered metal component production. Table 6.1 provides data for 1981 powder metal component production.

TABLE 6.1

POWDER METAL COMPONENT PRODUCTION BY COUNTRY IN 1981

	(1) Tonnes	(2) Population (Millions)	(3) Ratio (1)-(2)x10	(4) Automobile Production (millions)	(5) Ratio (1)-(4)x10
U.K.	8,500	55	0.15	1	.85
France	9,500	53	0.18	2.9	.33
West Germany	16,900	61	0.28	3.5	.48
Japan	55,000	116	0.47	10	.55
U.S.A.	115,000	216	0.53	10	1.15

Source: Materials & Design
October, 1982

All automotive manufacturers are undertaking studies of the possibility of extending the range of application of P/M components in order to reduce cost and weight. Typical of these studies, and existing applications, are:

- connecting rods for Porsche and Toyota producted by GKN

- powder metal inserts on cast camshafts from Toyota.

Hot forging of these items creates difficulties. For example, GKN has had considerable difficulty in producing connecting rods with reproducible dimensional tolerances and dimensional stability, especially during and after heat treatment. Difficulties have also arisen with respect to specific alloy compositions and the process routes. For these reasons, alternatives to the existing methods of powder metal component manufacture are under development at a large number of companies.

New process routes under development or only recently commercialized include:

- hot forming, where both the blank and die are heated;

- hot isostatic pressing (HIP) of rapidly solidified metal powders (RSR);

- pseudo isostatic pressing;

- injection moulding of powder metals.

6.2.3 New Non-Ferrous Alloys and Matrix Composites

New non-ferrous alloys, especially lightweight and/or high temperature materials, are receiving increasing attention from aerospace companies.

Also receiving attention are new materials such as discrete metal matrix composites (DMMC) and mechanically alloyed (MA) metals. All of these materials offer significant strength, weight and thermal properties over conventional materials. They are, however, generally considerably more expensive and difficult to process. Most of the uses for these materials are in applications such as fighter aircraft and large commercial aircraft.

Most of these new materials are based on powder metallurgy and/or rapid solidification technology. In all cases, the objective has been to create super pure materials with a very fine grain structure. The forging characteristics of these materials are relatively unknown, and extensive research in this area is required.

6.2.4 Isothermal Forging

Isothermal forging is a relatively new process designed to permit the precision forging of thin blade profiles. It is especially applicable to the forging of turbine blades for aircraft. The process is reported to offer cost savings of 20% and material savings of 40% over conventional forgings. Work in the field has been concentrated in the United States and in Germany, with some work in the United Kingdom and Japan.

Wyman-Gordon in the United States has recently commissioned an automated isothermal forging time for the production of titanium compressor and turbine discs and blades. The plant uses an 8,000 t press and operates under an inert atmosphere due to the use of molybdenum alloy TZM. The inert atmosphere is necessary as molybdenum sublimates at the deformation temperature when in an oxygen atmosphere. This condition makes the process very expensive.

An alternative isothermal processing route using cast IN100 dies has been developed by Thyssen Smiedtechnik in Germany. The results of the work are detailed below in terms of the cost comparison with conventional forging.

COST COMPARISONS FOR CONVENTIONAL AND ISOTHERMAL FORGING

TYPE OF COSTS	COST COMPARISON	
	Isothermal	Conventional
Material costs	60%	100%
Forging cost, incidentals, inspection costs, rejects	250%	100%
Specific die costs	100%	100%
Manufacturing costs, forged blade	100%	100%
Machining costs, incidentals, inspection costs and rejects	65%	100%
Manufacturing costs, finished-machined blade	80%	100%
Cost reduction	20%	

Source: Metallurgy, August, 1983

6.2.5 Ceramics

Advanced ceramics such as zirconium oxide, silicon carbide and other materials offering high temperature thermal cycle resistance may be a threat to forged components in certain applications. The most promising applications are turbocharger rotors for automobile engines and jet engine components such as guide vanes. Development work on these applications is well advanced in Japan and the United States, with Europe being somewhat behind the United States.

The Japanese, in particular, expect engineering ceramics to be an extremely important industry within five years. Advanced ceramics has been identified as one of the ten major technological innovations of the late 1980s and the 1990s. Private industry and the Japanese government are actively involved in research programs. One of the major Japanese ceramic producers, Kyocera, has made some engine components on a production basis. Kyocera, Hitachi, Isuzu Motors and Toyota Motors have all tested prototype ceramic diesel engines.

6.2.6 Castings

Castings represent a significant challenge to the forging industry. Many traditional forged products such as crankshafts, camshafts and connecting rods have already been largely converted to castings. This is especially true for crankshafts for small (1.5 l. and under) gasoline engines. In both Europe and Japan cast crankshafts now represent almost 100% of demand. The penetration of the diesel engine market is not as severe, but still represents approximately 50% of the market for diesel engines of under 2.0 l. If forgings are to recapture this market there will need to be a significant reduction in cost at all stages of manufacture.

A casting technology which poses a very serious threat to the forging industry is the squeeze casting technology developed by GKN Sankey in the United Kingdom. The process is especially applicable to the production of aluminum components, and is said to produce castings equivalent to forgings in terms of mechanical properties at a far lower cost.

VII - RESEARCH AND DEVELOPMENT REQUIREMENTS

Materials related research on sheet metals and forging stock is very limited in Canada. At the university level, there are only about eight individuals actively engaged in examining metal deformation behaviour. Research by the primary producers such as the steel mills is oriented to processing problems such as rolling. Work on establishing the forming behaviour of various grades of steel under different conditions is limited.

Metalforming research by the sheet metal and forging industries is almost non-existent in Canada, except for work on production systems. The industry relies on the results of foreign research for its technological requirements. In large part, the failure of the Canadian industry to undertake research is due to its small size. The industry also suffers from the lack of an organized forum such as a trade association through which to conduct joint research projects. Finally, the Canadian industry is generally unaware or unwilling to utilize the services, expertise, and facilities of university and government laboratories and scientists. The end result of this lack of research on metalforming is a lack of knowledge of the forming characteristics of various alloys in Canadian press and forge shops.

As discussed throughout this report, the Canadian metalforming industry requires additional research work on such items as:

- forming characteristics of HSLA sheet;
- cheap, easy to use methods to evaluate mechanical properties and formability of sheet materials in the press shop;
- 3-dimensional CAD/CAM programs which have a finite element analysis capability and can be used on small computers for die design. These would be of the "expert" type.
- welding properties and electrode design for use with coated steels, especially galvanized steels;

- characterization of forming properties of galvanized, electrogalvanized and bake hardenable steels;

- better characterization of flow stress data for forging alloys under cold and warm forging conditions;

- simple, cheap, easy-to-use tests to evaluate the forgeability of materials;

- data on the use and selection of forging lubricants;

- information on the process variables affecting the forging industry in terms of:
    - die life
    - production rate
    - product quality;

- information on the response of various alloys to heat treatment;

- better characterization of the machinability of microalloyed and direct quenching steels.

APPENDIX "A"

List of Companies/Organizations Interviewed

APPENDIX "A"

LIST OF COMPANIES/ORGANIZATIONS INTERVIEWED

CANADA

Stelco - Research and Development Centre
Dofasco - Research and Development Centre
McMaster University - Dr. John Duncan
    - Dr. John Sowerby
Selox Manufacturing, Toronto
Hayes-Dana Inc. St. Catharines
    - Chassis Division
    - Forge Division
Thompson Products Div. of TRW Canada, St. Catharines, Ont.
Welland Forge Ltd., Welland. Ont.
Atlas Steel Ltd., Welland, Ont.
EFT Tools Ltd., St. Catharines. Ont.
John Deere Canada Ltd., Welland, Ont.
Butler Metal Products Ltd., Cambridge, Ont.
Galt British Forge Ltd., Cambridge, Ont.
A.G. Simpson Ltd., Toronto, Ont.
Canada Metal Co. Ltd., Forge Division, Toronto, Ont.
Brockhouse Canada Ltd., Toronto, Ont.
Canadian Metal Rolling Mills, Toronto, Ont.
Budd Canada Ltd., Kitchener, Ont.
De Havilland Aircraft, Toronto, Ont.
Lofthouse Brass Mfg. Ltd., Whitby, Ont.
Elan Tool and Die Ltd., Chatham, Ont.
Dominion Forge Ltd., Windsor, Ont.
Fabricated Steel Products, Windsor, Ont.
American Can of Canada, Toronto, Ont.
Supreme Aluminum Industries, TorontoOnt.
Automotive Hardware Ltd., Toronto, Ont.
Tamco Ltd., Windsor, Ont.
General Motors (Oshawa), Oshawa, Ont.
AIOI Engineering Ltd., Toronto, Ont.
General Aluminum Forgings, Winnipeg, Man.
Boeing of Canada, Winnipeg, Man.
Versatile Manufacturing, Winnipeg, Man.
General Motors Canada, St. Catharines, Ont.
Tecumseh Metal Products, Windsor, Ontario
National Auto Radiator, Windsor, Ontario
International Harvester, Hamilton, Ont.
Fleet Industries Ltd., Fort Erie, Ont.
Brown Boggs Foundry & Machine, Hamilton, Ont.
RJ Stampings Ltd., Montreal, P.Q.
Canadian Racing Plate Co. Ltd., Niagara Falls, Ont.
Modular Architectural, Cobourg, Ont.
Nailor-Hart Ltd., Toronto, Ont.
National Machine Products Ltd., Toronto, Ont.
Newark Tool Machine Ltd., Toronto, Ont.
Opus Ferrum Ltd., Toronto, Ont.
Plymouth Tool and Stamping, Agincourt, Ont.

Premier Metal Industries Ltd., Mississauga, Ont.
Rheem Canada Ltd., Oakville, Ont.
Rideau Aluminum and Steel, Ottawa, Ont.
Rieke Ltd., Brampton, Ont.
Sigma Tool and Machine, Toronto, Ont.
Stanley Precision Ltd., Hamilton, Ont.
Ahoy Industries Ltd., Vancouver, B.C.
Delta Tooling and Manufacturing Ltd., Toronto, Ont.
Electronic Metalform, Markham, Ont.
Ideal Roofing Ltd., Ottawa, Ont.
Jacmarr Manufacturing Ltd., Kitchener, Ont.
Jones Manufacturing Ltd., Stratford, Ont.
Leigh Metal Products Ltd., London, Ont.
Lenworth Metal Products Ltd., London, Ont.
Lennox Tool and Die Ltd., Mississauga, Ont.
Ontario CAD/CAM Centre, Cambridge, Ont.
Mark Hot Inc., Montreal, P.Q.
CAMCO Inc., Hamilton, Ontario

UNITED STATES

Forging Industries Association, Cleveland, Ohio
Batelle Columbus Laboratories, Columbus, Ohio.
Eaton Corporation, Marion, Ohio
Chrysler Corporation, Detroit, Michigan
Ford Motor Corp., Detroit, Michigan
Park Drop Forge, Cleveland, Ohio
Otto Konigslow Mfg., Co., Cleveland, Ohio
Quality Stamping Products, Cleveland, Ohio
Bettcher Manufacturing Corp., Cleveland, Ohio
Federal Stampings Inc., Rochester, N.Y.
TRW Inc., William Div., Buffalo, N.Y.
Wm. P. Stein & Co., Rochester, N.Y.
Boehm Pressed Steel Co., Cleveland, Ohio
Automatic Stamp Products Co., Cleveland, Ohio
Ford Motor Corp., Canton Forge Div., Canton, Ohio
Republic Steel, Canton, Ohio
Metal Flow Corp., Holland, Michigan
Trans-Matic Corp., Holland, Mich.
Whirlpool Corp., Benton Harbour, Michigan
Precision Stamping Co., Brighton Michigan
Brighton Tool & Die Inc., Brighton, Michigan
Dana Corporation Tech., Centre, Ottawa Lake, Michigan
Progressive Metal Forming Inc., Hamburg, Michigan
Forming Technology Co., Royal Oak, Michigan
Alliance Tool Corporation, Rochester, N.Y.
Denler Metal Products, Buffalo, N.Y.
Curtis-Wright Corp., Buffalo, N.Y.
Dana Corporation, Reading PA
Alcoa Inc., Forge Division, Cleveland, Ohio

JAPAN

Toyota Motors Corporation
Isuzu Motors
Lobster Tool Company
Okuma Machinery Works Ltd.
Aida Engineering
Kikuchi Metal Stamping Co.
Kawasaki Steel
Nisshin Steel
NKK Steel
Nippon Steel
Sumitomo Metal Industries
Japan Iron and Steel Federation
Kubota Ltd.
Steel Castings and Forgings Association of Japan
Aichi Machine Industry Co., Ltd.
Akebono Kikai KK.
Capal Co., Ltd.
Daito Communications Apparatus Co., Ltd.
K.K. Dowa Seiskusho
Fuji Electric Co., Ltd.
K.K.Fujimi Kogyo
Ishikawa Kogyo K.K.
Itoki, Ltd.
Katayama Kogyo K.K.
Kawatetsu Kenzai Kogyo K.K.
Y.K. Kodaira Seisakushyo
Nakanishi Kinzoku Kogyo K.K.
K.K. Masuda Seisakusho
NDC Co., Ltd.
NEC Corp.
Nippon Light Metal Mfg. Co., Ltd.
Nissan Motor Co. Ltd.
Sanko Kogyo K.K.
Takano K.K.
Yamamoto Electric Industrial Co. Ltd.
Daiichi Tanzo K.K.
Goto Drop Forging Co., Ltd.
Furukawa Aluminum Co., Ltd.
Hokuriku Kogyo K.K.
K.K. Kato Tekkosho
Pacific Metals Co. Ltd.
Riken Tanzo K.K.
Shimizu Kohan K.K.
Shin Nippon Drop Forging Co., Ltd.
K.K. Yamazaki Kikai Seisakusho

EUROPE

Sweden

Sveriges Mekanforbund (industry trade association)
Botors-Kilsta AB
Pressmetall AB
IVF (government research laboratory)
Hasselfors Preciform AB
Tors Hammare AB

Germany/Austria

Krupp Stahl AG
Daimler-Benz AG
Voest-Alpine AG

France

Societe Nationale de l'Estampage et de la Forge (trade association)
Arbel Industrie
A.L.D.E.S.
Societe Forgeal
Vallourec
Societe Brechet

United Kingdom

EPAG Ltd.
GKN Forgings Ltd.
Firth-Derihon Stampings Ltd.
Smith-Clayton Forge
TRF Pland Ltd.
Cameron Iron Works
W. J. Wild Manufacturing Co.
G.L. Technology Ltd.
Light Metal Forgings Ltd.
Leslie and Company Ltd.
Doncasters Sheffield ltd.
Doncasters Monk Bridge Ltd.
Drop Forging Research Association
Samual Groves and Co. Ltd.
Rooke of Redditch Ltd.
Robert Dutton and Sons Ltd.
Frederick Woolley and Sons Ltd.